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SOME RECENT ADVANCES IN PHOTOGRAPHY.

BY FRED. E. IVES.

The Lecturer was introduced by Prof. EDWIN J. HOUSTON, as follows:

It is unnecessary at the present stage of the world's progress to insist on the advantages of photography. We are fortunate in having with us this evening as a lecturer, on "Some Recent Advances in Photography," one who is himself a pioneer in this department of applied science. I allude to Mr. FREDERIC E. IVES, a distinguished inventor in the field of photo-mechanical engraving, by which the production of type-printing plates directly from nature is made possible, and who was the first to devise and employ a practical process for obtaining accurate monochrome photographs of objects in all colors, or, as these pictures are styled, isochromatic photographs.

Mr. IVES then spoke as follows:

There is so much to be said on the subject of recent advances in photography, that it would take several lectures to cover the ground fairly well; I have therefore engaged only to speak of *some* recent advances in photography, and shall devote most of my time to those branches with which I am most familiar.

The most important recent advances in photography are the rapid gelatine bromide dry plate process, the isochromatic or color-sensitive processes, film photography, and the platinum and bromide paper printing processes—all of which have come into use within ten years past. The same period has also witnessed great advances in the applications of photography to the printing press, including the first commercially successful production of type-printing plates direct from ordinary photographic negatives.

THE DRY PLATE PROCESS.

The modern rapid gelatine bromide dry plate differs from the old wet collodion plate in being from ten to 100 times more sensitive, and in keeping for years before exposure or development. The increase of sensitiveness is valuable for many purposes—especially for making photographs of rapidly-moving bodies and objects that are dimly lighted; their keeping qualities render them useful for a great variety of purposes for which wet collodion plates are unsuitable. Because of these advantages, the introduction of this process has very greatly extended the application of photography, which is now largely employed by scientists in the pursuit of their investigations, by artists to assist them in their labors, by travellers to secure souvenirs of their journeys, and by thousands of people of both sexes, young and old, in the pursuit of pleasure.

The first successful gelatine bromide dry plates were made by Dr. Maddox, an amateur photographer, in England, in 1871; and the first gelatine emulsion commercially produced was advertised for sale by Mr. Burgess, in 1873. These emulsions were not remarkably sensitive, although somewhat more so than wet collodion plates. It was not until 1878 that Mr. Bennett, another amateur photographer, discovered that an emulsion of extraordinary sensitiveness could be produced by prolonged digestion at 32° C. In that year many experimentalists produced plates that were prob-

ably equal in every respect to the best commercial dry plates of to-day.

It took several years to convince practical photographers generally of the superiority of the gelatine dry plate method, but it has now superseded the collodion process for nearly all purposes, and thousands of important photographs have been made by it that would never have been made by the older method. The list includes photographic maps of the heavens, photographs of star and solar spectra a hundred times more perfect than could be produced on wet collodion plates, photographs of lightning flashes, balloon photographs, photographs of animals in motion and birds on the wing, etc.

One of the most popular applications of this process by amateurs is in the production of instantaneous pictures, by daylight with the so-called detective camera, and at night by the magnesium flash light.

FILM PHOTOGRAPHY.

Film photography is a method of producing the rapid gelatine bromide process negatives on paper instead of glass. This method offers the important advantage that, as the support for the sensitive film is extremely light and flexible, it can be used from a roll, and a great many exposures made upon the contents of a single roll holder. After development, the film negatives can be stripped from the paper support, preserved between the leaves of books and printed from as well and as quickly as glass negatives. This method is most useful to travellers, but is not likely to be adopted to any extent for home work. Lantern slides have also been made on these films, and a hundred of them may be carried in a pocket without inconvenience.

THE GELATINE BROMIDE PRINTING PROCESS.

The gelatine bromide printing process is an application of the gelatine bromide process to the production of positive prints by development. Suitable paper is coated with the gelatine bromide emulsion, and the development of the picture is effected with ferrous oxalate. The extreme sensitiveness of this paper makes it the easiest method we have for producing large prints from small negatives. The prints have a neutral tone that is pleasing and artistic.

THE PLATINUM PRINTING PROCESS.

The platinum printing process gives about the same effects as the bromide paper process, and is cheaper, but can be employed only for contact printing, or with the solar camera.

ISOCHROMATIC PHOTOGRAPHY.

Next in importance to the rapid gelatine dry plate process, is the isochromatic, or color-sensitive process. Ordinary photographic sensitive plates are comparatively insensitive to the green, and still more so to the yellow and red of the spectrum, so that those colors photograph much too dark, while blue and violet photograph too light. By means of plates made sensitive to the green, yellow and red rays, and employed in conjunction with light filters of colored glass, this defect may be corrected. Many paintings and art objects that could not be photographed successfully in the ordinary way because of their colors, are now reproduced in a most satisfactory manner by this method, which is variously known as the isochromatic, orthochromatic, and color-sensitive, or correct-color-tone process. Bromide of silver is made sensitive to the green, yellow and red rays, by treatment with certain organic compounds, such as chlorophyl, cyanine, eosine, etc.

Dr. H. W. Vogel, of Berlin, was the first to discover that bromide of silver can be made sensitive to color in this manner. In the course of some experiments in spectrum photography, he observed that plates prepared by a certain process showed relatively more green sensitiveness than ordinary collodion bath plates, and at once set to work to discover the cause. It appeared that it might be due to the color of the film, which was reddish, and he tried the effect of dyeing the film, hoping that the light absorbed and held in the film by the dye would be forced to act upon the sensitive salt. It would be contrary to all known physical laws for the mere coloration of a sensitive film to produce this result, but Dr. Vogel found that certain dyes did, in some way, produce color-sensitiveness, and he went so far as to produce, in his laboratory, a photograph of a blue ribbon on a yellow background, in which the ribbon came out darker than the background. His effort to prove a false theory led to an important scientific discovery. His plates were not, however, sufficiently sensitive to color to have any com-

mercial value, having, indeed, far less absolute color sensitiveness than the ordinary uncolored rapid gelatine dry plate of to-day; nor was the sensitiveness distributed throughout the lower portion of the spectrum, as it must be, in order to permit of the photographing of all colors correctly at one time.

Becquerel and Waterhouse, who soon after confirmed Dr. Vogel's results, each discovered a new and better color-sensitizer. Becquerel, in 1875, announced that by means of chlorophyl he had made plates from one-tenth to one-fifth as sensitive to the deep red of the prismatic spectrum as to the violet. Waterhouse, in 1876, announced that he had obtained strong yellow-green sensitiveness with eosine; he also made photographs of colored objects on the eosine plates, but as he employed no light filter, the blue and violet rays still did nearly all the work, and he reported the experiment a failure. Ducos du Hauron, of Paris, made some use of both chlorophyl and eosine in experiments in heliochromy in 1876–77, but did not try to produce correct monochrome photographs of colors.

The first correct-color-tone photographs of objects in all colors were made by myself in the laboratory of Cornell University, in the summer of 1878. They were made with collodion bromide emulsion plates, sensitized with myrtle-chlorophyl and an infusion of tea, and exposed through a light yellow medium. These plates were from twenty-five to fifty times more red-sensitive than those of Becquerel, and had also relatively sufficient sensitiveness to all other colors. I published the method in 1879, but nobody tried it. Several years after, similar processes were announced in Europe, and, in 1886, the FRANKLIN INSTITUTE, after a careful investigation, endorsed my claim to priority. Measured by results only, this original process leaves nothing to be desired, except the colors themselves, and is not equalled by any other yet discovered. It is the *only* process that will photograph the deep red pigments successfully,—but it is a comparatively troublesome and delicate process to operate, and is successful only in a bright light, and with chlorophyl obtained from certain kinds of leaves. It is also impossible to keep chlorophyl without considerable loss of sensitiveness, and it has never been employed successfully with gelatine dry plates. After several years of experiment, erythrosine and cyanine have been generally adopted, because they can be successfully

employed with gelatine dry plates, which are far more convenient to use than collodion emulsion, and also more sensitive.

In order to show the characteristic action of the most remarkable color-sensitizers, I have made photographs of the prismatic solar spectrum on plates prepared as follows:

(1) Plain collodion bromide emulsion. Shows, with short exposure, no action in or below the green.

(2) Collodion emulsion, with erythrosine. Shows, with same exposure, enormous action in the yellow, a great deal in the green, and none whatever in the red. This is the most powerful yellow-sensitizer known.

(3) Collodion emulsion with cyanine. Shows, with same exposure, strong action in the orange-red and yellow, none in the green, and none in the deep red. This is the best red-sensitizer yet discovered for gelatine dry plates.

(4) Collodion emulsion, with year and a half old chlorophyl, which had been preserved by adding zinc powder to the alcoholic solution. Although the chlorophyl has lost two-thirds of its original sensitiveness to red and green, it is still superior to cyanine, both in extent and intensity of action, but has the disadvantage that it would have failed with a gelatine dry plate.*

Cyanine-erythrosine gelatine dry plates, although they do not compare at all favorably with chlorophyl collodion plates in *relative* color-sensitiveness, have greater *absolute* sensitiveness for all colors except deep red; and because of their greater general sensitiveness, easy preparation and keeping qualities, they have greater commercial value. The average photographer very much prefers good results by an easy process to better results by a more troublesome one.

It is also a lamentable fact that the number of photographers who have any scientific knowledge of this subject is exceedingly small, and much that is being said and published about it is either false or misleading.

In July, 1886, the Chairman of a London photographic society, who pretended to have tried the orthochromatic processes, said he had never seen a photograph in which blue came out darker

*Since delivering this lecture, I have discovered a simple and certain method of producing strongly color-sensitive gelatine bromide plates by means of chlorophyl. This method will be published soon.

than yellow. In December, of the same year, a well-known photographer said, at a meeting of the Photographic Society of Great Britain, that he believed orthochromatic photography to be a delusion; he added that he had not tried it, "nor did he intend to do so."*

Within three months past, a writer, having made some photographs on ordinary plates, exposed through a simple yellow color-screen, announced that "the orthochromatic processes" do not succeed in making red or orange photograph lighter than blue, but make the color defect somewhat less conspicuous! The author of "A History of Photography, written as a practical guide *and an introduction to its latest developments*," published within six months past, ignores the subject altogether. Others go to the opposite extreme, and speak of color-sensitive gelatine dry plates that "can be used without the color-screen," which is of course true, because *any* plate can be so used, but is, nevertheless, a very misleading statement when made in this connection.

The scientific and practical value of these methods has been sufficiently proved, and it is clear to me that the better they are known, the more extensive will be their employment for many purposes.

PHOTO-MECHANICAL ENGRAVING.

The earliest experimenters in photography recognized the desirability of a photographic method of producing type blocks from nature, and the subject received a great deal of earnest attention for a long time before any successful method was realized. The chief problem that had to be solved was the automatic translation of the graduated tints or shades of the photograph into pure line or stipple. A great variety of methods were tried, and a few good examples produced from time to time; but no mechanically accurate or reliable method was ever suggested previous to 1878. In August, of that year, Chas. Petit, of Paris, and myself, then at Cornell University, recognized, almost at the same moment, the principle upon which the first successful method was based. We did not, however, apply the principle in the same manner, and Petit's process was not commercially successful.

* On that occasion Mr. Thomas Bolas remarked, that "unless there was a grand conspiracy among eminent men in the scientific world to tell lies, there *was* something in orthochromatic photography."

THE IVES PROCESS.

The Ives process was introduced commercially in this city early in 1881. It has been described a great many times in book and magazine publications, and is now very well known. The invention is not, primarily, a plate-making process, but a process of producing, by purely photo-mechanical means, a substitute for the hand-made pen or crayon drawings formerly required in the production of printing blocks by the aid of photography. The first operation is the production of a photographic relief, by a simple, well-known method, with bichromatized gelatine. A film of bichromatized gelatine is first exposed to light under the ordinary photographic negative, then placed in water, where it swells up into relief, highest where the negative was most intense, and lowest where it was most transparent. A cast in plaster is then made from this wet gelatine relief; it has a perfectly white surface, but is high where a photographic print from the negative would be black, lower in the middle shades, and lowest in the whites. After the production of this relief cast, the process is purely mechanical and perfectly simple and scientific. An inked pad or film of elastic V-shaped lines or dots is pressed against the surface of the relief cast, until the lines or dots are completely flattened out where they meet the highest parts of the cast; when it is removed, there remains impressed upon the cast an ink picture having the appearance of an ordinary photograph, but made up of sharply defined lines and dots, which graduate in size like those of a wood engraving, and can be photo-engraved exactly like a pen or crayon drawing, or transferred to zinc or copper and etched into relief. I have some of the relief casts here, one of them bearing the ink stipple impression. The operation of producing the impression is, as you see, extremely simple, and the result is wonderful. The elastic lines of the printing pad being V-shaped, secure mechanically accurate graduation from deep shadows to extreme high lights, and the general effect can be greatly modified at will by changing the pattern of lines and dots. The best results are secured by the employment of a special elastic compound, and special ink, the composition of which has not been published.

Petit, whose original specification dates the same week as my own, blackened the surface of a white photographic relief, and cut in white lines, with a V-shaped tool, on a planing machine. Although

the principle is substantially the same, the processes are perfectly distinct, and Petit's was a practical failure.

For more than a year, the Ives process was the only one in successful commercial operation in the world. Its first rival was a method introduced by Meisenbach, in Munich, in the latter part of the year 1882.

THE MEISENBACH PROCESS.

In this method, the photographic relief is not required, and the definite negative is made, at one operation, from a photographic positive on glass, like the well-known window transparencies. In order to accomplish this, a glass plate, bearing a tint consisting of fine lines cut through an opaque film, is placed between the positive and the sensitive plate, to cut the picture up into lines. So far, there is nothing new in the method, and if it were not more than this, it would be utterly unscientific and practically worthless. To illustrate this fact, I have made a photograph of such a positive through such a ruled tint on a large scale, which I will show on the screen. It will be seen that the result is a mere skeleton of the picture; half of the detail is lost, and that which remains appears in lines that do not graduate in size, like those of a wood engraving, but only in color, like a photograph. It would be impossible to make a good printing plate from such a negative. It is essential that this interposer, technically known as a "grating," shall not only divide the picture into lines, but also cause those lines to graduate in size as well as in color, and that it shall do all this without completely obscuring any detail of the positive picture. There are several ways in which this can be accomplished in a strictly accurate, scientific manner, and one of these is suggested, though not fairly described, in Meisenbach's patent specification. He makes only two distinct claims, neither of which was sufficiently novel or specific to be allowed in the U. S. Patent Office. The first is merely a device for securing, with this method, the pattern of black cross lines in the shadows and white cross lines in the lights, which was already a recognized characteristic of the Ives process plates; the second is his means for securing the necessary graduation in the size of the lines. It is of interest to note that this last claim, which alone suggests the true inwardness of Meisenbach's method, has been generally omitted from printed descriptions of the process—probably because its significance was

not suspected. It consists of merely giving to the "grating" a very slight movement, at right angles to the direction of the lines during the exposure. This operation can be so conducted that the result will be as if each line of the "grating" graduated in color from centre to edge. Without taking the trouble to demonstrate the fact, I will state that in a negative made under these conditions, the lines will be graduated in size as well as in color, being thinnest where they are narrowest, and stronger at the centre than at the edges. It is possible to produce a "grating" that will give this result directly, without the movement, by molding in pigmented gelatine upon plate glass from a type metal plate ruled in V-shaped lines; the printing film employed in the Ives process becomes a most perfect "grating" of this character if soaked in a suitable solution of dyestuff and then dried. Another method, which requires no movement, is to employ a "grating" having very narrow transparent lines, place it at some distance from the positive picture, and use a lens diaphragm having a diamond-shaped aperture. There are still other methods equally as good or better. It will be seen that in each of these cases we have really another application of the V-shape principle that had already been recognized and applied in a very different manner by Petit and myself. But even with the most perfect means for graduating the lines, this method will not succeed if we attempt to make the definite negatives by a dry-plate process, because the lines, which should graduate in size only, will naturally also graduate in color. They can be made to approximate to the required character only by employing the collodion and silver-bath process for making the negatives, and taking care to keep the silver bath in a peculiar condition, which favors the development of a coarse-grained, intense, superficial image that intensifies readily up to the extreme edge of each dot or line.

A microscopic examination of negatives produced by the two methods I have described shows a very striking difference in the appearance of the lines; those in the Ives negative are perfectly sharp and smooth, while those in the Meisenbach negative are grainy and rough, especially in the parts that represent the shadows of the photograph. But this defect in the "grating" process does not prevent the production of good printing plates, and the Meisenbach process has been very successful in Europe,

where it has been operated under the personal supervision of Meisenbach himself. Its most marked defect is a tendency to produce muddy shadows, and considerable loss of color in the middle shades of the picture. The plates also require considerable fixing up, which is done very skilfully by burnishing, roulletting and re-etching. Considerable hand-work is also usually done upon the glass positive, to emphasize outlines, faint details, etc. The process itself is cheap enough to admit of the employment of skilled hand labor to help it out in this way, but many publishers decidedly prefer purely photo-mechanical work, which cannot distort outlines and change expressions.

There are new and better "grating" processes now in operation, perfectly distinct from that of Meisenbach, and combining some of the merits of each of the older methods, but they have not been published. Already these processes, none of which were in operation seven years ago, replace millions of dollars worth of wood engraving annually. In a single establishment in our own city, 3,000 of these plates were made during the past year, and hundreds of them have appeared in our illustrated magazines. I have prepared one frame of pictures to illustrate how perfectly these plates may be made to replace wood engravings. Eight pages have been taken from *Harper's Magazine*, four containing wood engravings and four Ives process plates of similar subjects. Three wood engravings are from artists' brush drawings, and three process plates are from similar drawings by the same artists. One wood engraving is from a photograph from nature, and one process plate is from a similar photograph made by the same photographer. The general effect is the same, and it is admitted by critics that the process plates, which only cost about one-third as much as the wood engravings, are quite equal to them in quality. The process plates here shown were finished without retouching of any kind—they are what we call "pure process work." But it must be confessed that many plates made by the same process are not as satisfactory as these, because the copy supplied, brush, drawing or photograph, is not so suitable for photo-copying.

There is one other kind of photography, which has never been successfully realized, but which I shall say something about, because I have to announce what I believe to be a definite and important step in advance. I refer to photography in colors.

HELIOCHROMY.

There are two distinct methods of making color photographs, in which the distribution of color is regulated by photographic action of the light itself. In one of these methods, the colors are produced directly by the action of light upon a peculiar silver compound; in the other, no colors are produced, but the action of light upon color-sensitive plates is made to regulate the distribution and combination of colors which constitute the final picture. Both of these methods have been made to produce pictures in which the blues, greens, yellows and reds of an object were represented in a general way by blues, greens, yellows and reds.

The first recorded observations on the photographing of colors by the first method, were made by Dr. Seebeck, of Jena, in 1810—twenty-nine years before the discovery of the Daguerreotype process. A brief translation that has been published, reads as follows: "When I directed the spectrum of a faultless prism (so placed that the incident angle of the front became equal to the refracting angle of the back) on white chloride of silver spread upon paper and still wet, through an opening of about five to six lines in the shutter, and to the distance where the yellow just meets with blue, and kept it by a proper arrangement in this position from fifteen to twenty minutes, I found that chloride of silver changed as follows: It had become red-brown in the violet (occasionally more violet, at other times more blue), and this coloration reached also beyond the line of the violet designated before, but was not deeper than in the violet. In the blue of the spectrum the chloride of silver became true blue, and this color decreasing and gradually getting lighter, extended into the green. In the yellow I found the chloride of silver mostly unchanged; sometimes it appeared to me more yellow than before; however, in the red, and often a little beyond the red, it had taken the red of a rose." Sir John Herschel, in August, 1839, alluding to results obtained in substantially the same manner, said: "The red is tolerably vivid, but is rather of a brick color than a pure prismatic red. The green is of a sombre metallic hue, the blue still more so, and rapidly passing into blackness. The yellow is deficient." Edmond Becquerel, in 1848, Neipce de St. Victor, in 1851, Poitevin, in 1865, and St. Florent, in 1873, made some advances upon this method, but the results obtained have never had any practical

value. The process is so insensitive as to require hours of exposure in order to secure camera pictures of objects illuminated by direct sunlight, and the colors obtained, which are neither correct nor sufficiently brilliant, cannot be fixed. The researches of M. Carey Lea, of this city, appear to have thrown some further light upon this subject, but have not yet helped to the production of any better results. Most people who are interested in this subject expect the problem to be solved by a method of this character; a few, including myself, do not.

Permanent and far more brilliant pictures have been made by the second method I have mentioned, which was originally suggested by Henry Collen, of England, in 1865, as follows:

"It occurred to me this morning that if substances were discovered sensitive only to the primary colors—that is, one substance to each color, it would be possible to obtain photographs with the tints as in nature by some such means as the following:

"Obtain a negative sensitive to the blue rays only; obtain a second negative sensitive to the red rays only; and a third sensitive to the yellow rays only.

"There will thus have been three plates obtained for printing in colors, and each plate having extracted all its own peculiar color from every part of the subject in which it has been combined with the other two colors, and being in a certain degree analogous to the tones used in chromo-lithography. Now it is evident that if a surface be prepared for a positive picture, sensitive to yellow rays only, and that the two negatives, sensitive only to blue and red, be superimposed either on the other, and be laid on this surface, the action of light will be to give all the yellow existing in the subject, and if this process be repeated on other surfaces sensitive only to red or blue, respectively, there will have been produced three pictures of a colored object, each of which contains a primitive color reflected from that object.

"Now, supposing the first great object achieved, viz., the discovery of substances or preparations, each having sensitiveness to each of the primary colors only, it will not be difficult to imagine that the negatives being received on the surface of a material quite transparent and extremely thin, and that being so obtained are used as above—*i. e.*, each pair of superimposed negatives to obtain the color of the third—that three positives will be obtained, each

representing a considerable portion of the form of the object, but only one primary of the decomposed color of it. Now, if these three positives be received on the same kind of material as that used for the negatives, and be then laid the one on the other, with true coincidence as to the form, and all laid upon a white surface, it will not be difficult to imagine that the effect would be, not only the representation of the form of the object, but that of its color also, in all its compounds.

* * * * * * *

"Although the idea I have endeavored to express in words may be utterly worthless, I am unwilling to let it slip away without notice, as it may, on the other hand, contain a germ which may grow and bear fruit in due season." *

Ducos du Hauron, of Paris, appears to have been the first to attempt to realize a practical process of this character. The theory of his method is substantially the same as that of Collen, but the details of his process were somewhat simplified. Instead of trying to produce plates sensitive only to simple colors, he proposed to employ plates sensitive to all colors, and to filter the light through suitable colored glasses, which amounts to the same thing. He also proposed to allow two colors to act upon each sensitive plate, instead of combining two negatives for the purpose of producing each pigment print; the result would be the same.

Now this method of Collen and Hauron is evidently based on Sir David Brewster's theory of the nature of light, which is, that there are only three primary colors, and that all the other colors and shades of color in the spectrum result from the combination of these in different proportions. It has been clearly established that this theory is false, and that the color of no part of the spectrum can be truly reproduced by the optical combination of other parts. On the other hand, it is true that the eye is readily deceived by

* Collen was Queen Victoria's teacher of drawing, and was not a photographer. His statement of his theory, if taken literally, is not perfectly consistent; he says "negative" when he means "sensitive plate," "sensitive to yellow" when he means "producing a yellow picture," etc., but he makes his meaning sufficiently clear when he adds, in one place, that he would employ "each pair of superimposed negatives to obtain the color of the third." If he had taken more time to formulate his theory, he would, doubtless, have stated it accurately.

such combinations, which may therefore be regarded as more or less successful counterfeits of the true colors. The painter who copies after nature does not attempt to secure green pigments that will analyze like chlorophyl in the spectroscope, but is satisfied to produce a color that appears the same to the eye, and readily does so. It is really possible to successfully *counterfeit* all the colors of the spectrum by means of three transparent solutions of seemingly pure color, separate and mixed in different proportions. A photographic method that would accomplish this selection and combination of type colors automatically, and in such a scientific manner as would invariably secure the representation of each distinct spectrum color by a definite and suitable color mixture, would, I believe, be the nearest approach to accurate photography in colors that we are likely ever to realize. Now it might appear, at first glance, that Hauron's process, although developed on a basis of false theory, would secure such a result. It will not. Although Hauron's description of his color-screens is not specific, from a scientific point of view, there is sufficient evidence that his process was, at best, merely calculated to divide the spectrum into three parts, each of which would be represented by one negative only, and by a single type color in the final result; a heliochrome of the spectrum itself, made in this way, would therefore be nothing more than three strips of even color, abruptly joined together at the edges, but combined in no other way. In practice, Hauron was very far from realizing even so much as this; a heliochrome of the spectrum itself, made by his latest and most approved process (1879), would be black where it should be red, reddish-black or brown where it should be orange, and red where it should be yellow. Albert, Bierstadt and others, who experimented with this method, obtained better results than Hauron, but all failed to realize a successful process.

This method, although it had to be abandoned as utterly unreliable, was found to reproduce many pigment colors very well indeed. This result was due to the fact that all bright pigments reflect the light of two or more parts of the spectrum, and in some cases, by mere coincidence, in such proportion as will secure for them approximately correct representation by a process that is incapable of producing a fair counterfeit of the spectrum. Inasmuch, however, as we do sometimes have to deal with nearly pure

colors, and the composition of the mixed colors is also infinitely varied, it is evident that a heliochromic process, in order to be successful, must be capable of counterfeiting the spectrum itself.

Such a process I have devised, and will now undertake to describe for the first time. As I have said, I reject the theory of three primary colors, recognizing the fact that the color of each part of the spectrum is perfectly distinct from that of every other part; I do not attempt the impossible feat of actually reproducing each ray of simple color, but I undertake to make each ray of simple color select, in a definite manner, and quite automatically, such a combination of type colors as will successfully counterfeit it to the eye.

Before proceeding to describe the process, I will illustrate the difference that may exist between true spectrum colors and very perfect counterfeits of the same. I will do this by analyzing various bright colors with a projection spectroscope. It will be seen that aniline yellow, which counterfeits the yellow of the spectrum, is really a perfect mixture of all colors except blue and violet. Aniline green, which counterfeits the dark green of the spectrum, is a mixture of green, blue and deep red. Aniline violet, which counterfeits the violet of the spectrum, is as much blue and red as violet. I could show you a great many other equally striking examples, but these are sufficient to illustrate my remarks.

In order that I may make the theory of my process clear in a few words, I will commence by giving a list of the requisites for carrying it out, as follows:

(1) Transparent colored solutions, which counterfeit three simple spectrum colors, and can be made to counterfeit all others by mixing in different proportions. I call these my "reproduction colors."

(2) Photographic plates sufficiently sensitive to all parts of the visible spectrum.

(3) Means for filtering out, in a strictly accurate manner, such colored rays, and in such quantity or proportion, as may be required.*

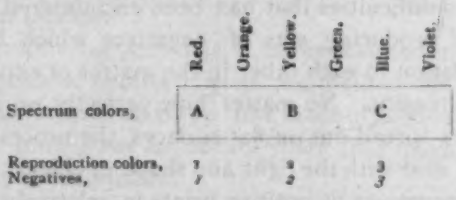
* Compound color-screens produced in the manner indicated in a communication published in this JOURNAL, **122**, 123.

(4) A camera that will produce three negatives simultaneously, of exactly the same size, and from the same (or very nearly the same) point of view.

(5) Means for producing, from the three negatives, pictures colored by the three solutions described above, and means for combining the three colored pictures.

All of these things I have; but to go into the details of their production would occupy too much time. My process, then, to be brief, consists of making three negatives, on color-sensitive plates, which are exposed simultaneously in a triple camera, behind light filters that are carefully adjusted to transmit to each plate just the kinds and amount of light that will cause the resulting negative to make a colored picture, which, when combined with the other two colored pictures produced in the same manner, will counterfeit the colors of the spectrum, or the colors and light and shade of any object. In order to accomplish this, each spectrum color that is not counterfeited by any one reproduction color, must, of course, be represented by two negatives, in such a manner as will secure a definite and suitable combination of two reproduction colors in the final result.

I believe I have made my meaning clear, but will try to illustrate by reference to a diagram of the spectrum.



If my reproduction colors *1*, *2* and *3* counterfeit the spectrum at *A*, *B* and *C*, the spectrum at *A* must be represented exclusively in negative *No. 1*, the spectrum at *B* exclusively in negative *No. 2*, and the spectrum at *C* exclusively in negative *No. 3*. Orange, occupying a position in the spectrum midway between *A* and *B*, is counterfeited by an equal mixture of reproduction colors *1* and *2*, and must therefore be equally represented in negatives *1* and *2*; in the same way, green in negatives *2* and *3*, and violet in negatives *3* and *1* (you will observe that I propose to counterfeit violet by a mixture of blue and red). Orange-red must be represented

in negatives *1* and *2*, but chiefly in *1;* orange-yellow in the same negatives, but chiefly in *2*, and so on.

All this can be accomplished in a most satisfactory manner, by the employment of special compound color-screens, which are adjusted by experiment upon the spectrum itself, in the manner originally suggested by me in a communication to the FRANKLIN INSTITUTE, in June, 1886. It is true the amount of labor involved in the adjustment of these color-screens is something enormous, but when it is done, it is done for all time.

The pictures may either be made in pigmented gelatine like Hauron's, or ordinary lantern slides from the negatives may be projected by means of a triple optical lantern and light of three colors. In the former method, the process is complicated by the fact that the pigment prints must in each case be of a color complementary to that of the mixture of color which produced the negative; in the latter method, each negative is represented by the reproduction color counterfeiting that which has been most active in its production. The latter method is the one I shall employ in demonstrating the process to you.

Although I have gone far enough into this subject to convince you that such a process must be a difficult one to reduce to successful practical operation, I have not yet spoken of one of the most serious difficulties that has been encountered; I refer to the difficulty of producing sets of negatives which bear a certain essential relation to each other in the matter of exposure, development and intensity. No matter how perfectly we may reproduce bright colors spread out on flat surfaces, the process will fail when we come to deal with the light and shade of objects in relief, if any one of the negatives or positive prints is relatively over or under-exposed, or over or under-developed, or too intense, or too thin. In such a case, a yellow which reproduced perfectly in the light shades of the picture, might appear orange, green or slate-colored in the shadows, or *vice versa*, and other colors would be equally imperfect. I find it necessary to prepare the three sensitive plates at the same time, with the same emulsion, and to develop them in the same developing solution, for the same length of time. Even with this precaution, the results are not perfect unless the sensitive plates are of a certain character, giving harmonious graduation from extreme high light to deepest shadow.

Evidently a process may be perfectly correct in principle and yet depend for its success upon conditions so difficult to attain that it will fail in practice. I believe that this process, although essentially difficult, may nevertheless be so perfected that it will not only counterfeit all the colors of Nature, but be practical and reliable in the hands of specialists who are properly instructed and equipped to operate it. If so, it will have very great value, even if applied only in the manner I shall show you to-night, and for a single purpose, which will suggest itself.

"The proof of the pudding is the eating." I have not yet proved the value of this process. Although I commenced work on it nearly eleven years ago, I have made only half a dozen full regular sets of negatives, and most of those were destroyed by fire at 715 Arch Street two years ago. My recent experiments have been devoted to perfecting certain details only. The single example that I shall show you to-night is my first and only attempt at a landscape, made more than six years ago, with comparatively crude apparatus and imperfect adjustment of color-screens. It is, however, a very remarkable picture, with colors scarcely less brilliant than they would appear on the ground glass of a camera, and substantially correct to the eye in every shade and detail.

I hope some time to be able to show hundreds of such pictures, all better than this one.

This illustration suggests one of the easiest and most profitable of the many possible applications of the method, viz., the illustration of popular lectures on travel, like those of Stoddard or Wilson. I feel sure the time is not far distant when that much, at least, will be successfully accomplished.

RUSSIAN AND AMERICAN PETROLEUM.

By Samuel P. Sadtler, Ph.D.

[*A Lecture delivered before the* Franklin Institute, *November 21, 1887.*]

American petroleum, or, more exactly, Pennsylvania petroleum, has, I am aware, been taken as a subject for lecture before this institution on several occasions already, notably in recent years by Mr. Chas. A. Ashburner, of the Second Geological Survey of Pennsylvania, and its geology and conditions of production as well as its refining and varied utilizations have been ably described. I am not aware, however, that it has been discussed in comparison with that equally wonderful and more recent production, Russian petroleum. It is my purpose then to describe briefly the conditions of occurrence of these two most important natural products, to note the chemical differences between the two "crudes," the differences of treatment made necessary in consequence, the characters of the respective products, and lastly the present and prospective commercial values of these two gifts of Nature. In speaking of the American field I shall speak, of course, essentially of the Pennsylvania production, for although we have Canadian oil, West Virginia oil, California oil and, prospectively of still greater importance, Ohio oil, the great bulk of the crude oil which is refined for illuminating and lubricating purposes, comes from what is called the Pennsylvania field. The extent and distribution of this oil-producing area is seen on the map (*projected on the screen*), taken from Mr. Ashburner's paper on the oil regions of Pennsylvania and New York, read before the Halifax Meeting of the American Institute of Mining Engineers, in September, 1885. Since the issue of this map, however, a considerable development has taken place in the neighborhood of Washington, Pa., so that an additional district, centring about the town of Washington, would have to be added. The combined area shown on Carll and Ashburner's map, as underlaid by oil-producing sands, is 369 square miles, stretching southwesterly from Alleghany County, N. Y., to Beaver County, Pa., on the Ohio River, the development centring about Bradford, McKean County, Pa.

The geological character of the oil-bearing strata has been very thoroughly studied by Messrs. Carll and Ashburner, of the Pennsylvania Geological Survey, and Prof. Peckham in his census report on petroleum. Mr. Carll has in his several reports, made to the Geological Survey, very clearly defined and described not only the groups of producing sand rocks, beginning with the three Venango County sands, the earliest producing rocks, but the different geological horizons, such as, to begin with the lowest, the Smethport sand, the Bradford and Alleghany group of sand rocks, the Warren and Clarendon sands, the Venango group before referred to, producing in Venango, Butler and Clarion Counties, and the Smith's Ferry heavy oil rock of Beaver County.

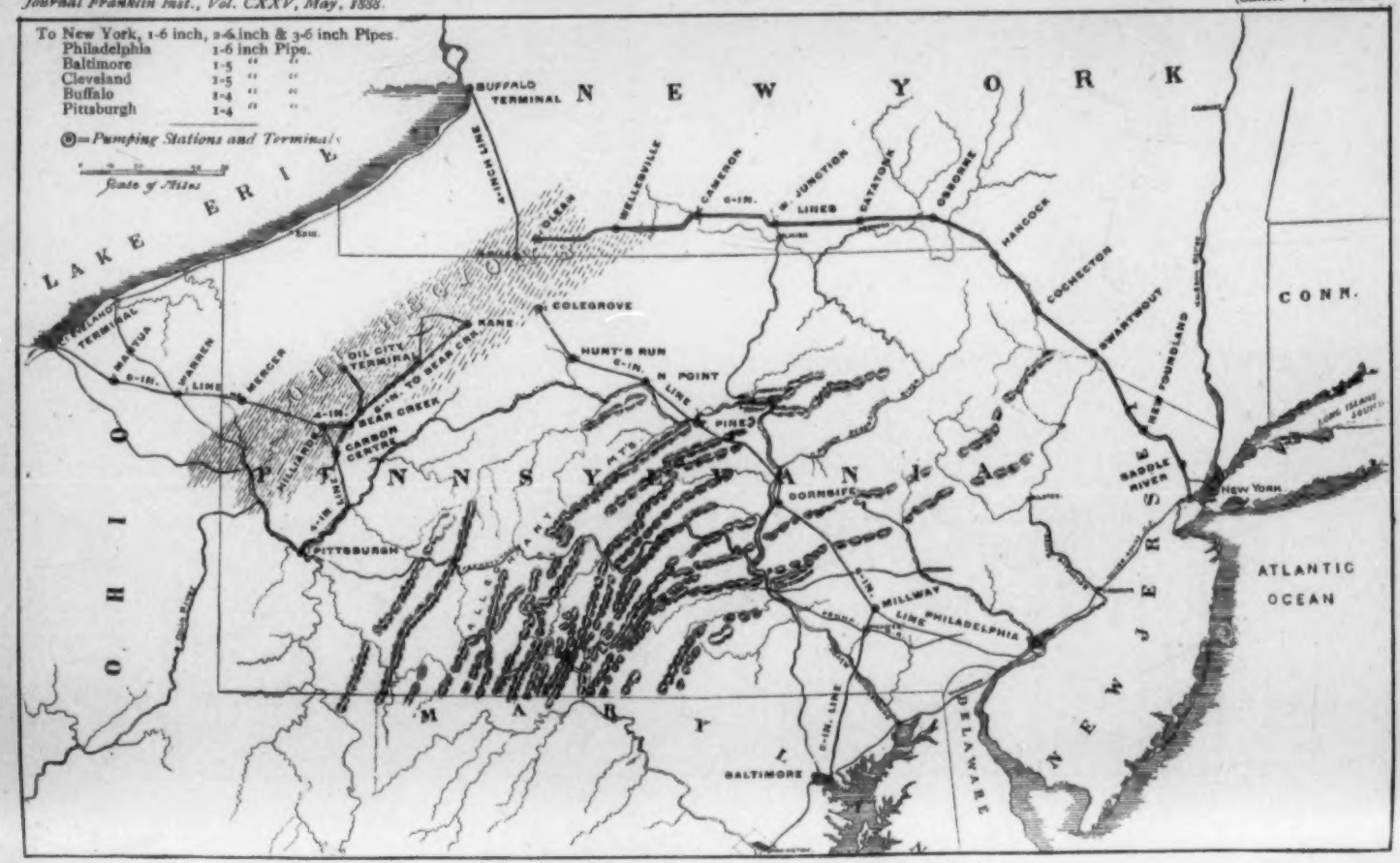
This sand rock of Western Pennsylvania varies in character from a coarse-grained uncemented sandstone, as in the Bradford district, to a pebble conglomerate of white or slightly colored opaque quartz, as in the Butler and Venango districts, overlaid by marls and slates, often highly silicated, forming very hard and impervious crusts. These formations, according to Prof. Peckham, "lie far beneath the influence of the superficial erosion, like sand bars in a flowing stream or detritus on a beach." "Taken as whole members of the geological series, the deposits lie conformably with the enclosing rocks and slope gently towards the southwest." The Bradford field, in particular, says Prof. Peckham, "resembles a sheet of coarse-grained sandstone, 100 square miles in extent, by from 20 to 80 feet deep, lying with its southwestern edge deepest and submerged in salt water, and its northeastern edge highest and filled with gas under an extremely high pressure."

While the oils found in this district may differ considerably in gravity, color, and undoubtedly somewhat in chemical composition, the differences are not fundamental, and with certain special exceptions, the crude oils from various localities are all brought together by the pipe lines and become mixed before going to the refineries. None of these Pennsylvania and New York oils contain any appreciable amount of sulphur or other impurity which would require a modification of the general refining methods. The heavy oils of Franklin and Smith's Ferry, Pa., and some few other localities, are so valuable for the manufacture of lubricating oils that they are collected and worked separately. The Pennsylvania crude oil has in general a dark greenish-black color, appearing claret-red by

transmitted light, and varies ordinarily in specific gravity from 0·782 to 0·850, or as it is frequently expressed, from 49° B. to 34° B. Exceptions to this general statement are the Washington County amber oil, the light colored oil of Smith's Ferry and some other natural yellow or amber oils. In chemical composition it is essentially composed of hydrocarbons of the paraffin series $C_n H_{2n+2}$, the gaseous and the solid members of the series being alike held dissolved in the liquid ones and smaller amounts of the olefine series $C_n H_{2n}$ and the benzene series $C_n N_{2n-6}$. According to Markownikow, as confirmed by Krämer, Pennsylvania petroleum also contains hydrocarbons of a series $C_n H_{2n}$, which he terms "naphthenes."

The crude oil of the Pennsylvania field is mostly refined in the three large cities of Pittsburgh, Pa.; Cleveland, O., and Buffalo, N. Y., or on the Atlantic seaboard, in close proximity to the ports of shipment. The transportation of the crude oil to these points, at first effected exclusively by railway tank cars, is now very largely effected by means of pipe lines. Most of these are now controlled by the National Transit Company, and a map, showing their main pipe line connections, is here given. Their lines include a line from Olean, N.Y., to New York, Bayonne and Hunter's Point, 300 miles in length, and consisting of two six-inch pipes for the entire distance, and a third six-inch pipe for a portion of the way, with a transporting capacity of 28,000 barrels per day; a line from Colegrove, Pa., to Philadelphia, 280 miles in length, consisting of one six-inch pipe; a branch line connecting with this at Midway, Pa., and running to Baltimore, Md., seventy miles in length, consisting of one five-inch pipe; a line from Hilliards, Pa., to Cleveland, O., 100 miles in length, of five-inch pipe; a line from Four Mile, Cattaraugus County, N. Y., to Buffalo, N. Y., seventy miles in length, of four-inch pipe, and a line from Carbon Centre, Butler County, Pa., to Pittsburgh, Pa., sixty miles in length, of four-inch pipe. The New York line has eleven pumping stations, about twenty-eight miles apart; the Philadelphia line has six stations; the Baltimore line is one line without a break; the Cleveland line has four stations, and the Buffalo and Pittsburgh lines each two stations.

Still another trunk line is that of the Tidewater Pipe Company, which is a six-inch pipe extending from Rixford, in the Bradford



MAP SHOWNIG THE NATIONAL TRANSIT CO.'S PIPE LINES.

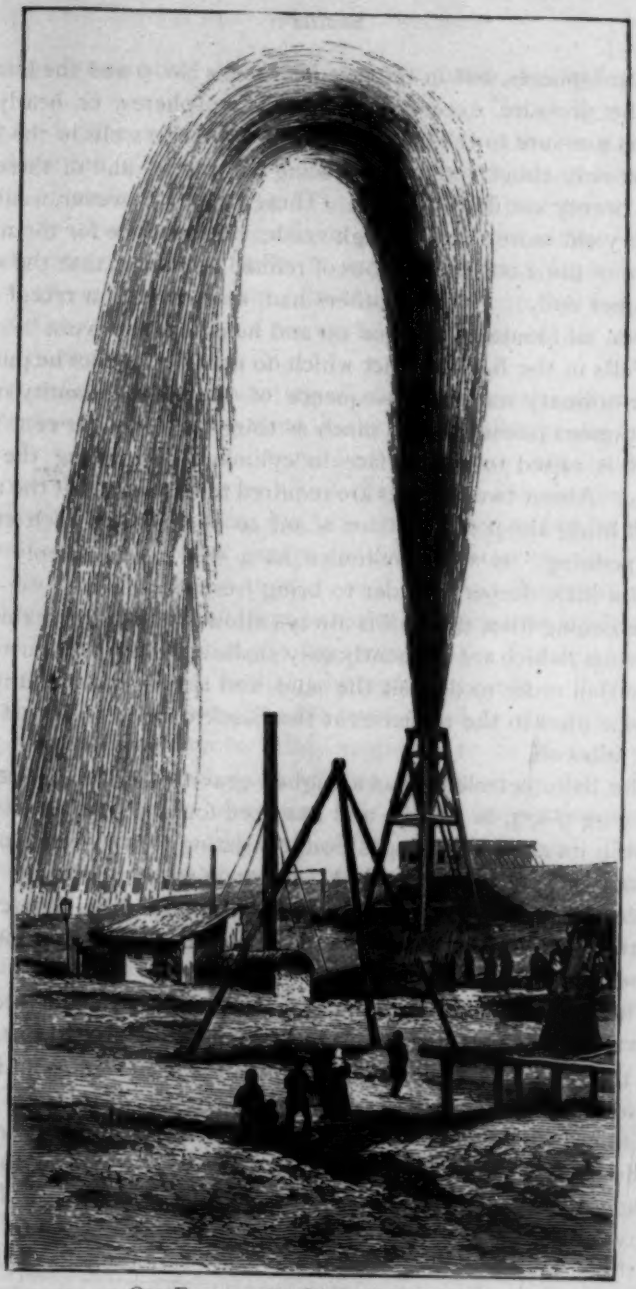
MAP SHOWING NOBEL BROTHERS' NETWORK OF PETROLEUM DEPÔTS IN RUSSIA.

field, to Tamanend, in Schuylkill County, where it connects with the Reading Railroad, by which the oil is transported to the seaboard in tank cars. The distance is 170 miles, and there are in this interval five pumping stations. The capacity of the line is 10,000 barrels per twenty-four hours.

If we turn now to the question of foreign petroleum production, we will find that only one locality deserves to be mentioned in comparison with our Pennsylvania production, viz: Baku, on the Caspian, in the Russian province of the Caucasus. The map (*projected on the screen*) will show the several known petroleum deposits of Europe and their geographical relation to each other, and to some extent the transportation facilities, as far as illustrated by the railway connections. The second or special map of the immediate Baku district will show the producing points and the refining centre on the outskirts of the town of Baku. As seen on this last map, there are two great groups of wells, the Surakhani and the Balakhani groups. The former exists on the site of the old fire worshippers' temple, where the petroleum gas has been issuing from the ground from the prehistoric period, 2,500 years ago, to the present. Only two or three companies carry on operations here. The majority are gathered at Balakhani, as a more copious supply was discovered here, and drilling operations were found to be more easily carried on.

The geology of this Baku district is not very definitely known. Vasilieff, in an article in the Russian *Mining Journal*, of September, 1886, states that the petroleum-bearing strata of the Caucasus belong to the Lower Miocene series of the Tertiary epoch, the deposits extending in a northeasterly to southwesterly direction, and the dip ranging apparently between 20° and 40°. The petroleum-bearing beds are composed of sand, calcareous clays, marls, and, in places, compact sandstones, often of great thickness, penetrated by bands of pyrites. The theory of Ludwig Nobel, based on numerous oil-well records made by his company, is that "the oil-bearing strata, originally running regularly in an almost diagonal direction, became dislocated and thrust hither and thither horizontally during some volcanic disturbance, and a sort of irregular cellular character given to the petroleum deposits." The peninsula of Apsheron is probably honeycombed with thousands of these oil cells, which seem to be for the greater part independent of each

other. They are found at all depths down to 825 feet, the extreme depth yet reached. The great Droobja oil fountain, which, in six months of 1883, poured forth about 55,000,000 gallons of oil, had reached a depth of 574 feet only, and while this was flowing at the rate of 2,000,000 gallons per diem, wells a stone's throw off and of lesser depth, were giving their daily supply of petroleum totally unaffected by it. Many of my audience have, perhaps, read newspaper items with regard to the terrific power and prolific character of some of these Baku oil wells, and may have put down much of the account to exaggeration. But numerous reliable and unbiased witnesses have united in giving figures that we must therefore accept. The largest flowing well we have had in Pennsylvania (the Armstrong No. 2) flowed for a time at the rate of over 6,000 barrels (or 260,000 gallons) per twenty-four hours. When Boverton Redwood, the Secretary of the British Petroleum Association, visited Baku in the fall of 1884, one of Nobel's capped fountains was opened for his benefit, and the sight then displayed is represented in the accompanying illustration. A solid column of oil, more than a foot in diameter, shot up to a height exceeding 100 feet, and continued to flow without diminution of violence as long as the valve remained open, forming a lake of oil to leeward of the well. The derrick was seventy feet high, and the oil column occasionally rose to at least double this height. This well (Nobel's No. 18) yields at the rate of 1,125,000 gallons per twenty-four hours whenever opened. It was, however, exceeded by the Droobja well before referred to, and Nobel's No. 9, each of which for a time having yielded double that quantity, or over 2,000,000 gallons per twenty-four hours, about eight times the amount yielded by the strongest Pennsylvania oil well known. The Nobel No. 9 was promptly capped, 1,000,000 gallons of oil being the total loss, but the Droobja well could not be gotten under control for over four months, and it is supposed that 100,000,000 gallons of oil were lost during this period. Not only this, however, but this Droobja fountain, which was from 200 to 300 feet high, threw out so much sand that neighboring engine houses and derricks were partly buried by it. The company owning it not only lost their oil, but were ruined by the damages they had to pay the surrounding well owners for flooding them with sand and oil. The maximum pressure previous to the discovery of these two fountains, had been



OIL FOUNTAIN. BAKU OIL REGION.

four atmospheres, but in the case of Nobel's No. 9 and the Droobja well the pressure exceeded thirteen atmospheres, or nearly 200 pounds pressure to the square inch. Of the 400 wells in the Baku district only about 100 are producing at present, and of these 100 some twenty are flowing wells. These twenty, however, would for a time yield more than enough crude oil to suffice for the manufacture of the 2,000,000 gallons of refined petroleum that the world consumes daily. Nobel Brothers had, moreover, at a recent date, fourteen oil fountains plugged up and held as a reserve.

Wells in the Baku district which do not flow, cannot be pumped in the ordinary way, in consequence of the large quantity of the sand present (sometimes as much as thirty to forty per cent.), and the oil is raised to the surface in cylinders resembling the sand pump. About two minutes are required to lower and lift the tubes, which bring about fifty gallons of oil to the surface each stroke. "Torpedoing" is so far unknown, as a well requires only to be bored a little deeper in order to bring fresh quantities of oil The oil on issuing from the well is always allowed to stand for a time in reservoirs (which are frequently only shallow ponds in the surrounding soil) in order to deposit the sand, and is then pumped through the pipe lines to the refineries at the Blacktown on the coast some eight miles off.

The Baku petroleum has a higher gravity than the American, averaging 0·873, or 31° B., and has been found to be entirely different in its chemical composition, consisting for the most part of hydrocarbons of the series C_nH_{2n}, isomeric with the olefine series and called "naphthenes." As will be seen later, this difference in chemical composition involves a difference in the refining methods and results.

The processes of distilling Pennsylvania petroleum are in a general way at least familiar to most of my audience, so I shall not take the time to go over them in detail. It is sufficient to say that although a normally conducted fractional distillation would give from thirty-five to fifty-five per cent. only of illuminating oil, by the process of "cracking," or destructive distillation, the percentage of illuminating oil may be increased to seventy-five to eighty per cent., the benzine fraction being from ten to fifteen and the residuum from five to ten per cent. On the other hand, the Russian petroleum does not yield over about twenty-seven to thirty

per cent. of illuminating oil of satisfactory quality, but will yield fifty per cent. of a very superior lubricating oil. Nobel Brothers, who are by far the most scientific and progressive in their methods, obtain about the following result: Benzine, 1 per cent.; gasoline, 3 per cent.; illuminating oil (32°C. or 89°F. Abel flash point), 27 per cent.; Soliarovi lubricating oil, sp. gr. 0·87, 12 per cent.; Veregenni lubricating oil, sp. gr. 0·89, 10 per cent.; lubricating oil, sp. gr. 0·905, 17 per cent.; cylinder lubricating oil, sp. gr. 0·915, 5 per cent.; vaseline, sp. gr. 0·925, 1 per cent.; liquid fuel, 14 per cent., and loss, 10 per cent; total, 100.

It is true that more illuminating oil than this twenty-seven per cent. is sometimes gotten by some of the Baku refiners, but it is of lower flash test. Prof. Beilstein, of St. Petersburg, has also proposed a method of cracking by which the yield of illuminating oil can be raised to fifty per cent., but it is not adopted as yet to any considerable extent. With regard to the character of the best Russian illuminating oil as compared with the best American oil, it is claimed by English and German experimenters that, while the Russian oil gives less light at the beginning of the burning when the lamp is full of oil and freshly trimmed, it affords a flame of somewhat greater permanence as the level of oil in the reservoir becomes lower, the difference being supposed to be due to the greater power which the Russian oil has of ascending the wick. In a comparison of the lubricating oils, there seems but little doubt that the Russian product has a distinct advantage. These lubricating oils from Baku petroleum contain little or no solid hydrocarbons, the greatest quantity obtainable amounting to only a quarter of one per cent. of the crude oil. They will show, therefore, exceptionally low cold tests. At the same time they have a remarkably high viscosity in relation to their specific gravity. This characteristic is exhibited in the following tabular statement, prepared by Boverton Redwood:

	Viscosity at 70° F.	Viscosity at 130° F.	Loss per cent. in Viscosity.
Russian oil (sp. gr. 0·913),	1400	156	88
American oil (sp. gr. 0·914),	231	66	71
Russian oil (sp. gr. 0·907),	649	135	79
American oil (sp. gr. 0·907),	171	58	66
Russian oil (sp. gr. 0·898),	173	56	67
American oil (sp. gr. 0·891),	81	40	50
Refined rape oil (for comparison),	321	112	65

It is true that the disproportion is chiefly at lower temperatures, the Russian oil losing its body relatively faster than the less viscous American oil. One distinctive feature of the Baku refining is the successful use they make of continuous distillation processes which are especially suited to Baku petroleums, as the quantity of burning oil separated being comparatively small the residuum is not very much less fluid than the crude oil. The stills, each of the capacity of 4,400 gallons, are arranged in groups or series of not more than twenty-five, and a stream of oil is kept continuously flowing through the entire number. The crude oil entering the first still parts with its most volatile constituents, passing into the next still has rather less volatile hydrocarbons distilled from it, and finally flows from the last still in the condition of residuum, which in Russia is termed *astatki*, or *masut*. The several stills are maintained at temperatures corresponding with the boiling points of the products to be volatilized. Superheated steam is used for all the stills, the steam being delivered partly under the oil and partly above the level of the oil; that is, in the vapor space above. The fuel used under all the stills in Baku is petroleum residuum, or "astatki." At many of the smaller works, the liquid fuel is simply allowed to flow upon the hearth of the furnace, and in thus using it, a very dense black smoke is evolved, whence the refining suburb of Baku has come to be known as the Blacktown. At Nobel's refinery, however, arrangements are adopted for burning the fuel with a proper admixture of air, and smokeless combustion is thus obtained. The part the astatki, or liquid fuel, now plays in the Caucasian district and in Russia is something not to be overlooked. It is the only fuel for locomotives, steamers and factory engines throughout this part of Russia. It has replaced wood and coal, and the use of it is now extending as far as Moscow to the north, Teheran to the south, Merv and Khiva to the east and Batoum to the west. In 1883, the aggregate export of astatki to Russia by all the Baku firms was 281,000 tons. On the other hand, the production was estimated as exceeding 500,000 tons, leaving, after making allowance for consumption in refineries, perhaps as much as 200,000 tons, or 50,000,000 gallons undisposed of. Enormous quantities are therefore allowed to go to waste. It is found in practice that with a good hydrocarbon furnace one ton of astatki goes as far as three tons of mineral fuel. Nobel Brothers alone are now turning out 450,000 tons of this fuel per year.

It remains now to glance at the methods of transportation and commercial development of Russian petroleum fields as compared with those of America. Our American system of pipe lines, extending to the seaboard, has already been illustrated. With the oil once at the Atlantic seaboard, its shipment either as crude or as refined is readily effected to any part of the habitable globe. Here, the Russians are at a disadvantage. Baku is on the Caspian Sea, on the border line between Europe and Asia, but with very imperfect means of communication. What there is may be said to have grown principally out of the wonderful energy and engineering ability of one man, Ludwig Nobel, a Swede by birth, although resident in Russia since his twelfth year. In 1875, his elder brother, Robert Nobel, began refining at Baku in a small way, with capital furnished by Ludwig, who had extensive engineering works at St. Petersburg. The Nobel Brothers found all the oil that was refined at Blacktown transported from Balakhani in barrels slung in two-wheeled Persian carts, termed "arbas." They laid down a pipe line eight miles long and paid its expenses the first season. They imported American oil-well borers and revolutionized the method of sinking wells. Then it was that, finding the transportation facilities too limited to allow them to ship their oil, Ludwig Nobel, the engineer, designed and had built the first of the oil-tank steamers that allowed him to ship his oil on the Caspian from Baku to the mouth of the Volga, a distance of 460 miles. This first liquid transport, or "cistern steamer," appeared on the Caspian in 1879. There is now a fleet of forty of them, the Nobel's owning twelve, carrying about 5,500 barrels apiece each trip. As the Volga at its wide mouth is very shallow, the tank steamers can proceed no farther than a locality termed "nine-feet sounding," about twenty miles from land, where the oil is transferred to oil barges, in which it is conveyed to Tsaritzin, the first railway point on the river Volga, 400 miles distant, where Nobel Brothers have established one of their great distributing centres for Russia. They have twenty barges on the Volga, and from Tsaritzin they distribute the oil by trains of oil-tank wagons. Of these, the Nobel's own 1,500, holding 2,600 gallons, or about ten tons of refined oil each. These are made up into trains of twenty-five wagons, so that the firm runs sixty such trains continuously in their distributing work. The accompanying map

shows the network of storage depots and distributing stations that the Nobel's have established throughout Russia and the adjacent countries. This system of storage depots is not merely a matter of convenience to them, but is to a large degree a matter of necessity. During at least four months in the year, the Volga is frozen over solidly, so that the oil needed for consumption during this winter term has to be accumulated at points accessible by rail connection. The oil trains of the Nobel's, therefore, are occupied during part of the year in collecting the oil in their storage depots, and during the winter in distributing it for consumption. This work is all directed from St. Petersburg, where Ludwig Nobel, the President of the company, resides. They are beginning also to ship their oil by tank steamers from Libau on the Baltic, where they bring it by tank cars, to Stettin, Hamburg and even to London. At Stettin, they have begun to erect storage tanks for the supply of the German trade.

In 1883, the Trans-Caucasian Railroad was finished, and oil is now shipped from Batoum on the Black Sea in quite considerable amounts to Mediterranean ports. A pipe line from Baku to Batoum has also been surveyed, and the Government concession having been obtained, it will likely be built in the near future.

The successful introduction of transportation of oil in bulk by means of oil-tank steamers on the Caspian, of course, led oil shippers to consider the question of using similar tank steamers for the transportation of American oil in bulk to Europe. Indeed, some slight experimenting in this line had preceded the adoption of the tank steamers on the Caspian, but the engineering difficulties connected with the shipment of oil in bulk for the voyage across the Atlantic were far greater, and hence greater precautions against danger had to be devised. Two large tank steamers, however, have been running this last year successfully, the *Crusader* and the *Andromeda*, the former to London and the latter to Bremen. The most important feature of their construction is the provision of auxiliary tanks above the level of the storage tanks and in communication with them. The storage tanks can thus always be kept quite full of oil, the auxiliary tanks serving to hold the surplus when the storage tanks become expanded by heat and supplying the deficiency when contraction takes place. The *Crusader* is provided with forty-five tanks, with an average capacity

of 125 barrels each, the *Andromeda* with seventy-two tanks, and carried in its first trip to Bremen 684,641 gallons of refined oil.

The statistics of production of both American and Russian oil and of exportations of the two, as far as statistics are attainable, are given in the tables in the Appendix.

I would, in conclusion, express my indebtedness for information on Russian petroleum matters to Boverton Redwood's lectures and articles in the *Journal of the Society of Chemical Industry*, to Dr. C. Engler's "Das Erdoel von Baku," reprinted from *Dingler's Polytechnisches Journal*, and especially to Chas. Marvin's work, "The Region of Eternal Fire," London, 1884. I am also indebted for personal favors to Mr. H. M. B. Bary, to Messrs. Fuller Brothers, and to the Atlantic Refining Company, of this city.

APPENDIX.

Table I.

Annual Production and Value of Petroleum in the United States, according to the Bureau of Mining Statistics, U. S. Department of the Interior.

	Production.		
1882,	30,053,500 barrels,	valued at	$23,705,698
1883,	23,400,229 "	"	25,740,252
1884,	24,089,758 "	"	20,476,294
1885,	21,842,041 "	"	19,193,694
1886,	28,110,115 "	"	20,028,457

Table II.

Annual Production of Crude Oil in the Baku District, according to Engler.

1881,	4,900,000	hundred kilos, or	3,500,000	barrels.
1882,	6,800,000	"	4,857,143	"
1883,	8,000,000	"	5,714,286	"
1884,	11,300,000	"	8,071,428	"
1885,	16,360,000	"	11,685,714	"

Table III.

Exports of Crude and Refined Petroleum from the United States for the Years 1884–85 and '86, according to the U. S. Bureau of Statistics.

	1884.	1885.	1886.
Crude petroleum exported,	79,679,395 gallons.	81,435,600 gallons.	76,346,480 gallons.
Valued at,	$6,102,810	$6,040,685	$5,068,409
Naphthas and light distillates,	13,676,421 gallons.	14,739,460 gallons.	14,474,961 gallons.
Illuminating oils,	433,851,275 "	445,880,518 "	485,120,680 "
Lubricating oils,	11,985,219 "	12,978,955 "	13,918,367 "
Residuum and tar,	126,269 barrels.	136,474 barrels.	47,474 barrels.
Value of the refined products,	$43,354,306	$43,631,058	$43,076,795

Table IV.

The Shipments of Baku Petroleum for the Years 1885 and 1886 are thus given in the U. S. Consular Reports:

(1) From Batoum via Trans-Caucasian Railway—

	1885.	1886.
Illuminating oil,	26,865,325 gallons.	39,321,005 gallons.
Crude, lubricating and residuums,	4,774,600 "	14,915,315 "
Total,	31,639,925 "	54,236,320 "

(2) Via Astrachan on the Caspian Sea—

	First Six Months of 1886.
Illuminating oil,	44,428,315 gallons.
Crude, naphthas and residuums,	79,866,200 "
Other products,	8,851,960 "
Total,	133,146,495 "

On SOME EARLY FORMS of ELECTRIC FURNACES.

No. 6. NAPIER'S ELECTRIC FURNACE.

By Prof. Edwin J. Houston.

Numerous suggestions have been made at early dates for utilizing the power of feeble electric currents in order to effect the reduction of various metallic ores. To accomplish this purpose the ores were dissolved by the action of suitable chemicals, and the electrolytic solutions thus obtained decomposed by the direct passage of the electric current.

In 1844, James Napier, of England, conceived the idea of preparing metallic ores, for the process of electric reduction, by heat in the place of chemical solution. This he accomplished by mixing the ores with certain fluxes and heating the mixtures to their point of fusion. The fused mass thus obtained was then subjected to the action of an electric current by the passage of which the reduction was effected.

The process suggested by Napier was a great advance over the purely chemical processes above referred to. Apart from the question of expense, the necessity for first obtaining a chemical solution of the ore to be treated, necessarily limited the class of reductions to which such a process is applicable. The comparative ease with which most ores can be reduced to the semi-fluid state by heating them in the presence of suitable fluxes is well known, and, where the electric resistance of such fluid masses is not great, the commercial practicability of the method proposed by Napier would appear to be assured.

Napier's process, it will be seen, is not unlike the method adopted at a much earlier date by Davy in his great discovery of the metals of the alkaline earths.

In carrying out his invention, Napier mixes the ores to be reduced with the fluxes and places the mixtures in crucibles of refractory materials, such, for example, as plumbago. These crucibles are covered on the inside with clay, except at the bottom, which is left uncovered. By this means the electric current is caused to traverse the molten mass from the surface to the bottom of the crucible.

The positive electrode of the decomposing battery is attached to an iron disc placed on the surface of the molten mass, while the negative electrode is connected with the outside of the crucible. Coke is sometimes used in place of the iron disc for this purpose.

Napier patented his furnace in England in 1844. His patent is numbered 10,362 of 1844, and is for "Improvements in treating mineral waters to obtain products therefrom, and for separating metals from other matters." Napier also took out letters-patent in Great Britain, No. 10,684 of 1845, for the same invention, the specification of which is the same as in the preceding patent. This latter patent covered the British colonies and other territory not protected by his former patent.

The following description is taken from the specifications of the preceding patents.

"The second part of my invention has for its object the application to metallic ores when in a fused state of a current of electricity, so as to separate therefrom the metals which they contain.

"I will proceed to describe the method which I employ in the treatment of copper ores, though the invention is applicable to ores of other metals which are capable of being held in fusion with fluxes. I take a large crucible, or other convenient vessel, made of an electro-conducting material, those I have used being of plumbago (common black lead). The inside of this vessel I line all around with a lute of clay, except the bottom, which I leave uncovered. The luting should be very thin and laid on in two or three coats, drying slowly between each, so as to prevent cracking. When the vessel is sufficiently luted and dried I put therein (with the usual fluxes) the regulus or calcined ore, which, when sulphurets are used, should have been well roasted so as to drive off as much as possible of the sulphur. I then place the vessel with its contents in an ordinary air furnace, keeping up the heat until the mass is in a state of fusion. In the meantime, I have prepared an ordinary voltaic battery of copper and amalgamated zinc charged with acidulated water, one part sulphuric acid to twenty-five parts water. To the positive wire of the battery, I attach an iron rod, having riveted at right angles to its extremity a flat disc of iron, the disc being a little smaller than the inner circumference of the crucible. To the negative wire of the battery I attach a simple rod or bar of iron. The matter in the crucible

being in a state of fusion and well fluxed, I place the above-mentioned disc of iron, which will now form the positive pole of the battery, on the surface of the fused mass, and keep the rod which is connected with the negative pole in contact with the outside of the crucible, the bottom of which thus forms the negative pole. The fused matter now forms a portion of the electric circuit; and the heat being kept up, the metal is gradually reduced and deposited at the bottom of the crucible."

The battery employed by Napier consisted of five pairs of plates for every hundredweight of regulus of thirty per cent. of metal. The internal resistance of the battery was quite low, as will be seen from the dimensions of the plates: "The size of zinc plates being three feet square, and the copper being doubled round the zinc in the usual way."

Napier did not limit himself to the use of the particular character or size of battery described. He says in the specifications of the patents before referred to: "The power of the voltaic battery, or other means of generating electricity which may be used, will vary for different ores, and I have found that if a larger battery be employed with the same quantity of ore, the time required for the extraction of the metal will be shorter, and *vice versa*; and if a more powerful voltaic combination be used a smaller sized battery or a shorter time will suffice."

The following additional details are given concerning the process: "Whether a crucible or other vessel or furnace be employed to contain the fused ore, it should have its bottom, or a sufficient portion of it at the lowest part, formed in the interior of plumbago or other suitable electro-conducting material with which the negative rod can come in contact. The positive pole should consist of an electro-conducting material, and I have found iron, as above described, the most convenient and satisfactory, although I have also found that coke may be used. The thickness of the wires or straps of metal used for connection should increase with the size of the apparatus. For the proportions above given I have found straps of ordinary sheet copper of an inch broad sufficient."

Structurally, the Napier electric furnace consists of the following elements in combination:

(1) A crucible or other receptacle of refractory material that is at the same time a conductor of electricity.

(2) A lining or luting applied to the inside of such crucible so as to necessitate the passage of the decomposing current through the melted mass to be treated.

(3) The combination with such a crucible of an external source of heat.

(4) The combination with the fused ore, contained in the crucible before mentioned, of the electrodes of a fairly powerful voltaic battery, or other electric source, so connected with the crucible as to permit the current to pass through the fused mass.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, *February 3, 1888.*

THE WELSBACH SYSTEM OF ILLUMINATION.

BY A. O. GRANGER.

[*Read at the Stated Meeting of the* INSTITUTE, *Wednesday, March 21, 1888.*]

W. P. TATHAM, Vice-President, in the Chair.

About the year 1880, Carl Auer, then a pupil of Prof. Bunsen at the University of Heidelberg, became interested in the subject of illumination. Bunsen particularly impressed upon Auer's mind that the present method of obtaining illumination from combustion of gas in the ordinary way, in which the separated carbon particles are made incandescent through the heat produced by the combustion of the hydrogen, was far from being economical, inasmuch as the amount of light yielded was but a small percentage of the energy contained in the gas, and gave it as his opinion that the light of the future would be obtained by first converting the illuminating gas into a heating flame through the medium of the well-known burner bearing his name, and then applying the heat so produced to bring to incandescence some refractory material. Young Auer revolved this suggestion in his mind, but before he had succeeded in obtaining any practical result the electric light changed the current of his thoughts. As is well known, in order to produce the incandescent electric light it is necessary that the carbon filament be used in a vacuum. Auer saw the expensiveness of this method,

and began a series of experiments to produce a filament made from refractory earths or oxides that could be used in the open air without being consumed. It was while engaged upon experiments of this nature that he produced the incandescent gas light now before you.

We all know that the idea of an incandescent light is not new, and every school-boy knows of the Drummond oxy-hydrogen lime light, but all lights of that character have failed to come into commercial use, because the material to be acted upon by the heat has always been present in considerable mass, and has required gas under pressure and a very high temperature to bring the mass to incandescence. But the Welsbach light is successful, because the oxides are produced in an extremely thin or attenuated form whereby the minimum of heat will produce the maximum of light.

Here is a complete burner, *Fig. 1* (*see frontispiece*). I will light it with the electric taper, and, of course, when that can be used, a match or any other competent source of heat will ignite the gas. You see, there is practically no explosion; in fact, there is less noise than in lighting an Argand burner.

I will describe the Welsbach burner very briefly: We use a modified, but very perfect form of the Bunsen burner (*Fig. 2*), the heat from which brings to incandescence the hood or mantle. This mantle, such as we have here (exhibiting), is knitted by machinery from fine cotton thread into a cylinder about 2 inches in diameter by 5 inches long. You see, it is soft and limp (*Fig. 3*). It is then dipped to the point of complete saturation in the chemical solution, which I will presently refer to, and then it is dried and attached by means of fine platinum wire to this vertical iron rod (exhibiting), with the horizontal loop at the top. Here is a mantle that has been saturated (exhibiting) and is all ready for the burning-out process, which consists in holding it over a Bunsen or a water-gas flame, whereby the cotton fibre is completely consumed, leaving nothing but the oxides that had adhered to the cotton (shrunken to about half the former size of the mantle, see *Fig. 4*) in the form of an extremely fine but coherent and refractory mineral skeleton, which perfectly retains the texture of the woven fabric. This is one of the great secrets of the success of the Welsbach system; no other method that at all approaches this having ever been discovered whereby an extremely small

amount of refractory material can be made to cover in a practical way so much surface.

There are three principal elements used in the manufacture of the solution in which the cotton cylinder or mantle is dipped, viz: lanthanum, zirconium and yttrium. These are produced respectively from the minerals cerite, zircon and samarskite, which are found in large quantities in Norway, Sweden, Ceylon, the Ural Mountains, and in our own country in North Carolina and elsewhere.

We have here some fine samples of the ores or minerals, and I will be glad to have anyone interested inspect them, as also the burners, etc., at the close of the meeting.

Heretofore these minerals have been considered very rare, and so they were so long as the only demand for them was for the collections of chemists and mineralogists. Now we can produce these crystals by the shovelful, and the cost of the oxides in one of these beautiful burners is but a few cents.

I will not weary you with the details of the method of reducing the ores to obtain these oxides as nearly chemically pure as possible, and will merely state that the result of the various operations employed is before us in the impalpable powder, of which we have here (exhibiting) a good sample, and from which the final impregnating solution is made by using certain proportions of the minerals.

Here is a bottle of the solution (exhibiting). It has a milky look, as you see, rather like lime water, and it is only necessary to vary the proportions of the oxides to produce any light from an intense white to a brilliant yellow.

The Welsbach patents were first acquired by the United Gas Improvement Company, of this city, and the original purchasers afterwards formed the Welsbach Company that now owns the system for the United States. It was early determined, after the managers had been fully satisfied in every particular as to the burner, to lay out plans and make an investment on a generous scale, and not to put any burners on the market until a considerable stock had been accumulated, so as to meet the large demand that was sure to come.

The Welsbach Incandescent Gas Light Company has a large factory at Gloucester, N. J., where the buildings cover some three

acres of ground. The company is introducing machinery and organizing its force to make 25,000 to 30,000 complete burners per day. It has erected its own fuel gas works, and, besides the machinery and apparatus for reducing minerals, has a complete chemical laboratory, machine shop, elaborate photometrical rooms, etc.

The working force is so organized that each step in the manufacture is carried on in a separate room. First comes the knitting of the mantle by machinery, and then a corps of girls attend to what is called the reinforcing or folding the mantle over at the top so as to have a larger amount of material through which to thread the platinum wire from which the mantle is suspended. The mantle is dipped in the solution and goes through a drying room, and then to the forming room, where it is given its shape, and then to the burning-out room, where the cotton is entirely consumed, leaving the refractory skeleton of the fabric behind, preserving intact the shape and appearance of the knitted cotton mantle. It is then mounted on the brass work or gallery, and we have the complete burner. For purposes of shipment the mantle, after having been burned as described, is dipped in a solution that entirely prevents any damage in transit.

Now, in introducing any new system of illumination, there are certain conditions necessary to success, and they must be recognized and fully covered.

(1) The brackets, chandeliers and gas fixtures that are in ordinary use must not be interfered with in any material way, and illustrating this point I will ask my assistant, Mr. Crisfield, to put one of these burners on that bracket on the wall (indicating).

There is an ordinary bracket, and an old-fashioned gas burner. You will see the facility with which the old burner is taken off and the Welsbach burner put on, only a few moments of time being required. (The change was made as Mr. Granger spoke.)

(2) The new burners must give a brighter, steadier and in every way a better light than the ordinary gas flame, so that the improvement will be decided at once upon seeing it. I think that point has also been covered and must be apparent to all present. (Pointing to the burners.)

Relative to the feature of economy, of which I will speak a little later, I will ask Dr. Wahl to kindly take a reading of these

burners to find the amount of gas used by the Welsbach and by the ordinary jet. Here is the meter and stop-watch.

(While Dr. Wahl was making the reading Mr. Granger continued):

(3) Any new burner coming before the public must also be easily lighted, easily taken care of, not liable to special derangement in ordinary practice or handling, and the cost of renewals must be moderate. This burner, while it is a mere skeleton, a mere ash, will stand all the banging it would get in ordinary use, and can be lighted just as easily as an Argand burner, with a match, or in any other way. (Illustrating by vigorously shaking a burner and then lighting it with an electric taper.)

(4) There should also be—and this point should be marked well—less vitiation of the atmosphere of the room. We all know that the combustion of gas in the ordinary way is imperfect, resulting in considerable vitiation of the atmosphere, and particles of carbon are set free as smoke or soot, but with the Bunsen flame this great objection is done away with, and there is also less oxygen consumed by reason of the reduced amount of gas burned.

(5) And above all, economy. While we may have a light that will radiate less heat—one that will give a perfectly white light, so that colors can be detected at night—a steady light, not affected by draughts, and a light that is more beneficial to health and in every way pleasanter and more desirable—yet if it possesses no economy in the use of gas, it will not find public favor to a large extent. In this burner we have no hesitation in asserting that with any kind of illuminating gas there is an efficiency of at least two to one in favor of the Welsbach burner. In other words, two and a half feet of coal gas consumed with the Welsbach burner will give a better light than five to six feet of gas consumed in the ordinary way. Now, to apply that practically in Philadelphia: Our coal gas is sold at $1.50 per 1,000 feet. With the Welsbach burner the gas would be less than seventy-five cents. That's not very scientific, but it is eminently practical.

Dr. Wahl says the ordinary gas jet is burning nearly eight feet, while about two and three-quarter feet are being consumed by this Welsbach burner.

[Although the meter reading had been made with great care, Dr. Wahl, being surprised at the result, said he would like to take

another reading of the ordinary gas jet, causing Mr. Granger to exclaim *sotto-voce*, "Give the gas a chance," which was received with much laughter.]

Dr. GOLDSMITH:—I would like to ask how you account for the cohesion? Is there an interlocking of the particles, or fusion?

Mr. GRANGER:—No, there is no fusion. As you see, this mantle is a reticulated mesh work, and when the cotton is entirely burned away, we have a perfect oxide copy of its former shape—a mere shadow, but there is, nevertheless, a certain amount of cohesion of the particles that make them hold together.

Dr. GOLDSMITH:—That is what I wanted to get at.

Mr. GRANGER:—That is one of the great points in this system. Others have attempted to produce an incandescent light, but the material while enduring a few hours, would disintegrate and fall to pieces, but there are certain elements used in the manufacture of this solution that give a toughness to the mantle which is very remarkable.

Dr. GOLDSMITH:—I can readily understand it if any fusion takes place of any elements, but it puzzled me to see how they otherwise held together, at first.

Mr. GRANGER:—It is a decided advance, and is only accomplished by certain chemicals that produce that result. There is, however, no fusion of the particles. We have not heat enough in the gas flame to fuse them.

Dr. WAHL:—The meter readings hold about the same relation to each other as before.

Mr. GRANGER:—While Dr. Wahl is completing that reading, I would say that I was recently in New York City, at the home of a friend, who is a Director of the Welsbach Incandescent Gas Light Company of New York, and he had on a side wall-bracket two Welsbach burners, each in a shade or globe similar to this (indicating), and below the bracket was a decorated plate (or plaque as I suppose the ladies would call it), set in a velvet frame, and this was hanging from the gas bracket by a little silvered wire, and a friend was there looking at the beautiful light. He seemed a good deal puzzled—looked at it a moment, and then said: "Does the current come up these wires?" (Merriment.)

A MEMBER:—What is the average life of the mantle?

Mr. GRANGER:—About 500 to 1,000 hours, or about six months of ordinary use, represented by the 500 hours.

I would like also to refer to one other point. I have a letter here from Prof. A. M. Mayer, of the Stevens Institute of Technology, whom many of you doubtless know, addressed to Mr. Shapleigh, who is the superintendent and chemist of the Welsbach Company's works at Gloucester. He says:

"One of the Welsbach burners I had handed me by Prof. Morton, who has several of them. I have been making experiments on it. Among other valuable properties for a lecturer and for researches in physics is the fact that it has furnished me at last, after many trials with other sources of radiant heat, with a source which is so constant that when placed before a Melloni thermo-pile it causes a deflection of the Thomson galvanometer (connected with the pile) which is absolutely constant, so that the reflected beam of light from the galvanometer remains in one fixed position on the screen. This lamp will hereafter be a requisite for all of these thermo-electric instruments."

I will now light the different burners so that you can see the variation in color. We have hardly pressure enough here to run all the burners, the gas having to pass through the rubber tube and test meter, but you see there is a white light, and this is the yellow. I will light this one so that you can see the effect of the globe or shade. (Does so.)

Dr. WAHL:—I would like to ask whether you have experimented as to the resistance of the filament to withstand a jar or shock given to the brackets, to determine whether or not by any accidental shaking, or any knock that it would be likely to get in use, it would be injured?

Mr. GRANGER:—In reply to that question I would say that I recently saw a statement made by the editor of a London scientific journal that he understood these mantles to be so fragile, that the least vibration, even that amount produced by a heavily-loaded team passing in the street, would disintegrate the mantle. This is the best answer to that statement (tapping the burner sharply several times), and I don't think that in ordinary use, unless a person went at it intending to break it, it would ever receive rougher handling than I have just given it, and so we hold that it is practical for ordinary use.

I would also say that this burner is quite an improvement over the burner that was brought to the attention of the United Gas Improvement Company a year ago. Then, a chimney was required

several inches taller than this, and of the pattern or style known as the Student lamp chimney, having a constricted portion here (indicating), and the burner was rather troublesome to light, requiring some skill. You had to turn it just so, and put the match at the right place just at the right time; but all that has been overcome now, and we use the Argand chimney of commerce; you can light it and use it just the same as any other burner, and hence we feel that it is now a practical success. I would say for the information of my hearers that in a few weeks the Philadelphia Welsbach Company will open its rooms at 122 South Twelfth Street, where there will be a number of burners on exhibition, both white and yellow, and also burners used with fuel gas.

We have here a small tank of fuel water gas (hydrogen and carbonic oxide) made at our works in Gloucester, from the decomposition of steam by passing it through a bed of glowing anthracite coal. I will ask my assistant, Mr. Beard, to turn on the gas, so that we can light this burner. (Exhibits the burner with fuel gas.)

Dr. WAHL (noticing the ease with which Mr. Granger lighted the burner from the top) said: "It seems to me that one of the best evidences of the practicability of the Welsbach filament is the fact that it can be lighted from above. There is a certain amount of explosive mixture formed in that chimney, and, as is well known, when the attempt is made to light it, it ignites with a slight explosion—and the fact that the filament will stand that sort of treatment seems to me a point in its favor. I am surprised to see the filament holding out and behaving as it does, because in reading of it I was led to believe that it was extremely fragile.

Mr. GRANGER:—We have here a very good form of Prof. Bunsen's burner, with a modified tip, so that there is almost no audible explosion and we are not troubled with lighting back, which is a very great fault in the ordinary Bunsen. There (pointing) we have a fine light with the fuel gas, and we have made experiments with this burner with natural gas, and find, in Pittsburgh, that we get twelve candles per foot. From the ordinary city gas here (coal gas) we get about eight candles per foot, so that the range may be said to be from eight candles per foot with coal gas to twelve candles per foot with natural gas. We have also tested it with gas produced by the Springfield and other gas machines, and get practically the same result as we have here,

showing that the burner is adapted to anything in the way of vapor or gas that contains sufficient heat.

Photographs have also been taken at night with this burner, and with an exposure of from one and a half to two minutes, negatives have been produced equal in every particular to the best sun negatives, showing that the actinic properties of the light are very perfect.

Mr. TATHAM:—How low can you turn it down without putting it out?

[Mr. Granger turned a burner down so low that some person in the audience said: "It's out." But it was not out, as was shown by turning the gas on, when the brilliant light instantly reappeared.]

Mr. Ives then projected the burner and mantle on the screen, greatly enlarged, after which the discussion was closed.

GENERAL THEORY OF JOINTED BOW GIRDERS.

BY E. A. WERNER, C.E.

PART I.—EXTERNAL FORCES.

Any structure is a system of material points acted upon by external and internal or elastical forces, which is subject to certain conditions—in our case to the condition to remain on certain points or planes—the abutments. All the forces acting upon the structure must be in equilibrium, when the structure shall resist the action of these forces.

Now, we know that the conditions of equilibrium of a free, rigid system of material points acted upon by forces can be expressed mathematically and that any system can be turned into a free, rigid system, in making the forces homogeneous and replacing the conditions to which it might be subject by forces of the same kind.

Hence in order to apply to any structure mathematical calculation, it is necessary to transform it into a free, rigid system, by expressing the internal or elastical forces and the conditions, that the structure has to remain upon the abutments by external forces.

This is done by substituting for the abutments their reactions and by cutting the structure at any point into *two* parts, removing one part and replacing its internal forces by external ones in the section. Which of the parts of the structure is removed does not matter, as both systems of external forces, acting upon the parts of the structure separated by the section, are *necessarily* in equilibrium by means of the equal but inversely directed internal or elastical forces.

If we express then mathematically the deformations of the structure produced by the action of the forces and add the conditions that all the forces are in equilibrium, we can—the form of the structure and the way of loading being known—finally express these forces themselves in mathematical form and subject them to numeric calculation.

But as all the structures, we have to deal with, are structures lying in a plane and remaining in this plane under the action of the loads, it is evident that, for our use, the above quite general problem may be restricted without detriment. Calling "line of thrust," the geometrical locus of the point of application of the thrust in the structure, the following disquisitions are thus conducted under the supposition that: "*the line of thrust be a plane curve and remain a plane curve under the action of the forces or loads.*"

If we assume now, as it is generally accepted, that the normal and tangential (shearing) forces produce strains equally distributed over the elements of the section, and that the moments produce, parallel to the axis of bending, equal but increasing strains in ratio with the distance from this line in the sections of the structure, we know that the conditions, which must be fulfilled to comply with the assumption of a plane line of thrust, remaining a plane curve under the action of the forces or loads, are:

(1) *The plane of the line of thrust must be a plane of symmetry of the whole structure; and*

(2) *The external forces—the loads and reactions of the abutments—must act in the plane of the line of thrust.*

We have then, according to the above premises, for expressing the forces in the structure the equations of equilibrium of a free rigid system.

Referring the system to a rectangular system of co-ordinates, with the origin lying in the left abutment and the X axis passing through the abutment joints, these equations are:

$$\Sigma(x) - H = o$$
$$\Sigma(y) - V = o$$
$$\Sigma(x\,y) - M = o$$

wherein:

$\Sigma(x)$, $\Sigma(y)$, $\Sigma(x\,y)$ represent the sum of all the internal forces of the removed part in the direction of the X and Y axis and their moments, and H, V, M, the same sums with regard to the external forces—the loads and the reactions of the abutments.

These equations give the internal or elastical forces $\Sigma(x)$, $\Sigma(y)$, $\Sigma(x\,y)$ as functions of the external ones, and I must first show how those external forces can be expressed in mathematical form, and their maximal and minimal values found.

I. EXTERNAL FORCES.

The following denominations and assumptions will be made:

The structure shall always have three joints, one on each abutment and one somewhere else between the abutments. I shall always call A the left abutment, B the right abutment, C the top joint, and suppose the latter to lie in the middle of the span. In the rare cases, when this is not so, it will be easy to make the necessary corrections.

The line of thrust is the geometrical locus of the points of application of the thrust in the structure. The line of thrust shall always be a plane curve, of such shape, *that a line parallel to a line connecting top and abutment joint* $A\,C$ or $B\,C$ shall have *no more than one point of contact in each half bow.*

The line of thrust shall always remain a plane curve under the action of the loads.

The line of thrust shall be referred to a rectangular system of co-ordinates, with the origin in the left abutment and the X axis passing through the two abutment joints.

No restriction is made as to the way of loading the structure or the numeric value of the loads.

The structure is supposed to be loaded quite arbitrary with loads at rest and moving loads, both kinds single or together, covering in any way the whole or parts of the structure, continuously or in single points.

G_1 be the sum of all the loads from the left abutment, to a point $x_m\ y_m$.

G_2 the same sum, from the point $x_m\ y_m$ to the top joint.

G_3 the same sum from the top joint to the right abutment.

$g_1\ g_2\ g_3$ be the abscissæ of the point of application of $G_1\ G_2\ G_3$.

I shall always represent the loading, regardless to the way of loading or the numeric value of the loads, in using for *moving loads a heavy line*, for *loads at rest a light line, extending over the whole space covered with loads.*

ACB = the line of thrust.

l = span of the structure, centre to centre of joints A, B.

f = height of the top joint C above the abutment joints A, B.

Δx_m = length of th mth panel.

μ_m = angle of the tangent of the line of thrust in the point $x_m\ y_m$ with the X axis.

μ_f = angle of the line $A\ C$ or $B\ C$ with the X axis.

Q, Q_1 = the vertical component of the abutment reactions.

H = the horizontal component of the abutment reactions.

V_m = sum of the vertical shearing forces, *without the component of the thrust* in the point $x_m\ y_m$ (vertical shearing forces of a beam of the same span and loading).

R_m = sum of the shearing forces *normal* to the line of thrust in the point $x_m\ y_m$.

S_m = sum of the *vertical* shearing forces in the point $x_m\ y_m$.

M_m = sum of the moments of all the forces in the point $x_m\ y_m$.

m is an index, defining the position of the point under consideration $x_m\ y_m$. I shall count from the left abutment, 1. 2. 3. . . . m, $(m+1)$, $(m+2)$ . . . . . $(n-2)$, $(n-1)-n$.

With these denominations we have now directly from *Fig. 1* of *Plate I*:

$$Q_1 = \frac{G_1 g_1 + G_2 g_2 + G_3 g_3}{l} \tag{1}$$

$$Q = G_1 + G_2 + G_3 - Q_1 = \frac{G_1(l-g_1) + G_2(l-g_2) - G_3(l-g_3)}{l}$$

$$Hf = Q_1 \frac{l}{2} - G_3\left(\frac{l}{2} - g_3\right) = Q\frac{l}{2} - G_1\left(\frac{l}{2} - g_1\right) - G_2\left(\frac{l}{2} - g_2\right) \tag{2}$$

$$H = \frac{G_1 g_1 + G_2 g_2 + G_3 (l - g_3)}{2f} \tag{3}$$

$$M_m = Q x_m - G_1 (x - g_1)_m - H y_m = Q_1 (l - x)_m - G_2 (g_2 - x)_m - \\ - G_3 (g_3 - x)_m - H y_m \tag{4}$$

$$M_m = G_1 g_1 \left(1 - \frac{2fx + ly}{2fl}\right)_m + G_2 \left(x - g_2 \frac{2fx + ly}{2fl}\right)_m + \\ + G_3 (l - g_3) \left(\frac{2fx - ly}{2fl}\right)_m \tag{5}$$

(See *Fig. 2.*)

$$V_m = Q - g_1$$

$$R_m = V_m \cos \mu_m - H \sin \mu_m$$

$$S_m = \frac{R_m}{\cos \mu_m} = V_m - H \operatorname{tng} \mu_m \tag{6}$$

$$S_m = - G_1 g_1 \left(\frac{1}{l} + \frac{\operatorname{tng} \mu_x}{2f}\right)_m + G_2 \left(1 - g_2 \frac{\operatorname{tng} \mu_x}{2f}\right)_m + \\ + G_3 (l - g_3) \left(\frac{1}{l} - \frac{\operatorname{tng} \mu_x}{2f}\right)_m \tag{7}$$

and as known:

$$S_m = \frac{d M}{d x} = \frac{M_m - M_{m-1}}{\Delta x_m} \tag{8}$$

The above equations give the external forces of a jointed bow structure in mathematical form, and I will now show, how the positions of the loads inducing their maximal and minimal values are found.

$Q\ Q_1\ H$ = Reactions of the abutments.

For loads at rest, the reactions of the abutments are constant.

For moving loads, they increase with increasing loading and reach their maximal values with a completely loaded girder and *vice versa* for the minimal values.

But quite generally *H increases* with *decreasing* height of the bow.

MOMENTS.

Loads at rest.

We know that quite generally:

$$S_m = \frac{d M}{d x} = \frac{M_m - M_{m-1}}{\Delta x_m}$$

Hence M is a maximum in all points in which $S_m = o$ or in all points in which:

$$o = V_m - H \operatorname{tng} \mu_m$$

or:

$$o = \frac{f}{\frac{l}{2}} \cdot \frac{-G_1 g_1 + G_2 (l - g_2) + G_3 (l - g_3)}{G_1 g_1 + G_2 g_2 + G_3 (l - g_3)} - \operatorname{tng} \mu_m \quad (9)$$

The general course of the moments is thus as follows:

M always is zero in the abutment and top joints, between which it reaches as many maxima or minima as the above equation has roots. The number of these roots depends upon the way of loading and the form of the line of thrust.

I will first consider the maxima and minima depending upon the form of the line of thrust.

We deduct from equation (9):

$$\operatorname{tng} \mu_m = \operatorname{tng} \mu_f = \frac{f}{\frac{l}{2}} \quad (10)$$

This expression is easily constructed. It represents the point of contact with the line of thrust of a line parallel to $A\ C$ or $B\ C$ (see *Fig. 3*). As often as the parallel to $A\ C$ or $B\ C$ is tangent on the line of thrust as many maxima or minima of M will occur and in as many parts, comporting all alike, the structure will be divided. (*Fig. 4.*)

I have thus assumed that the form of the line of thrust is such, that a parallel to $A\ C$ or $B\ C$ has only one point of contact in each half bow. In case of more than *one* point of contact the results obtained under the above assumption must be applied to each of the subdivisions of the girder separately.

The other roots of equation

$$V_m - H \operatorname{tng} \mu_m = o$$

depend upon the way of loading and the value of the loads. They cannot be pointed out *a priori*, but it will never present any difficulty to find them for any specified loading. For the rest, they occur only for *quite* special loadings.

Under ordinary circumstances, the only maximum and minimum of M occuring is that corresponding to:

$$\operatorname{tng} \mu_m = \operatorname{tng} \mu_f$$

In using the values of M as ordinates, the changes of M from point to point in the structure can be graphically represented. *Fig. 5* shows the shape of the curve of the moments in a structure, with only positive or only negative moments. *Fig. 6*, in a structure with alternative positive and negative moments.

MOVING LOADS.

With moving loads the value of the moments will not only change from point to point in the structure, but also with any new position of the loads. Still, in considering first a certain point in the girder, that is, in making $x_m\ y_m$ constant, we can find the variations of M in the point under consideration, while the loads are passing over the structure and in applying the resulting rules to every point in the structure deduct the general rules governing the positions of the loads, inducing the maximal and minimal values of the moments in each point of the structure.

Eq. (5).

$$M_m = G_1 g_1 \left(1 - \frac{2fx + ly}{2fl}\right) + G_2 \left(x - g_2 \frac{2fx + ly}{2fl}\right) +$$
$$+ G_3 (l - g_3) \left(\frac{2fx - ly}{2fl}\right)$$

is of little use in the above form for these investigations and must thus first be brought in a more convenient form by transforming the coefficients of $G_1\ G_2\ G_3$:

$$\left(1 - \frac{2fx + ly}{2fl}\right) = a \qquad (11^a)$$

$$\left(x - \frac{2fx + ly}{2fl} g_2\right) = b \qquad (12^a)$$

$$\frac{2fx - ly}{2fl} = c \qquad (13^a)$$

I shall call these coefficients henceforth $a\ .\ b\ .\ c$.

For the transformation, I shall introduce an auxiliary figure by drawing the lines $A\ C$, $D\ C$, connecting the abutment and top joints and $A\ C$ the perpendicular in A (*Fig. 7*), or the triangle $D\ A\ C$.

I shall call this triangle henceforth the "*deciding triangle*," as the position of the line of thrust, with regard to this triangle,

decides of the way, in which the moments, or in fact, as we will see, all the forces are acting in the structure.

I shall call then, furthermore:

ζ' = ordinate of the line $D\,C$.

ζ = ordinate of the line $A\,C$.

Then:

$$a = \left(1 - \frac{2fx + ly}{2fl}\right) = \frac{\zeta' - y}{2f} \tag{11}$$

$$b = \frac{2fx + ly}{2fl} = \frac{\zeta + y}{2f} \tag{12}$$

$$c = \frac{2fx - ly}{2fl} = \frac{\zeta - y}{2f} \tag{13}$$

Still b can be expressed in another way, which will prove most useful, in introducing an auxiliary quantity.

If we consider b, we see, that it depends upon x and g_2. But for—

$$g_2 = g_m = \frac{2fl\,x}{2fx + ly} \tag{I}$$

it becomes zero.

g_m as a and c is simply a function of $x_m\,y_m$ or of the form of the line of thrust and can consequently be graphically constructed. g_m is the abscissa of the point of intersection of the two lines $D\,C$ (the upper side of the deciding triangle) and $A\,y$.

The demonstration follows directly from the figure (*Fig. 8*).

In introducing g_m in $a\,b\,c$, we have then the following three forms of M:

$$M_m = a_m\,G_1 g_1 + b_m\,G_2 + c_m\,G_3(l - g_3) \tag{I}$$

$$M_m = G_1\,g_1\left(\frac{\zeta' - y}{2f}\right)_m + G_2\left(x - \frac{\zeta + y}{2f}\,g_2\right)_m + \\ + G_3(l - g_3)\left(\frac{\zeta - y}{2f}\right)_m \tag{I^a}$$

$$M_m = \left[\frac{1}{g_m}(g_m - x)\,G_1 g_1 + G_2(g_m - g_2)\frac{x}{g_m} + \right. \\ \left. + G_3(l - g_3)\left(\frac{2g_m - l}{l}\right)\frac{x}{g_m}\right]_m \tag{I^b}$$

Equations (I) are the *pivot* equations of the whole theory. The expressions of all the other forces can be reduced to them.

The positions of the loads inducing the maximal and minimal positions of the moments are now found by investigating the action and influence of the different factors composing the total value of M.

If we consider to that effect Eq. I, we see that the total value of M depends upon *two* quite different factors:

(1) $G_1\ G_2\ G_3$ representing the way of loading and the numeric value of the loads. These quantities are *independent* of the form of the line of thrust, and

(2) $a.\ b.\ c.$, functions of y and ζ, representing the influence of the form of the line of thrust and of the deciding triangle.

The influence of $G_1\ G_2\ G_3$, the first factor is easily explained.

$G_1\ G_2\ G_3$ are functions of the loads only and necessarily always positive, changing only their numeric values. The absolute value of the moments will thus only be influenced so far, as its numeric value will be greater or smaller accordingly as $G_1\ G_2\ G_3$ are greater or smaller.

The influence of the second factor, or of the coefficients $a\ b\ c$, is not so simple. It is *two-fold*, as not only the coefficients can assume any absolute value, but also can become *positive* or *negative*.

The influence of the absolute value of $a\ b\ c$ upon the total value of M is similar to that of $G_1\ G_2\ G_3$. The greater $a\ b\ c$, the greater M and *vice versa*.

Quite different is the influence of the signs of $a\ b\ c$ upon the total value of M.

As $G_1\ G_2\ G_3$ are always positive, *the signs of $a\ b\ c$ decide the sign of the total value of the moments or the way, in which the moments are acting in the structure*. The signs of $a\ b\ c$ are thus the principal factors in deciding the total value of the moments and their maximal and minimal values.

The signs of $a\ b\ c$ depend upon y and ζ. Hence in considering a certain point $x_m\ y_m$ in the structure,—$x_m\ y_m$ is then constant,—and in varying the form of the line of thrust, we will find the alterations of $a\ b\ c$ in the point under consideration. To that effect $A_1\ C, A_2\ C, A_3\ C, A_4\ C$ represent in *Fig. 9* different forms of the line of thrust, $x_m\ y_m$ be the point under consideration. $D\ A\ C$ the deciding triangle.

Then:

$$a = \frac{\zeta^1 - y}{2f}$$

is positive or negative accordingly, as:

$$\zeta^1 \gtrless y$$

or a is:

positive in all structures, whose lines of thrust lie *inside* or *below* the deciding triangle; *negative* in all structures, whose lines of thrust lie *above* the deciding triangle; *zero* in all structures, whose lines of thrust *coincide* with the side $D\,C$ of the deciding triangle.

$$c = \frac{\zeta - y}{2f}$$

is positive or negative accordingly, as:

$$\zeta \lessgtr y$$

or c is:

positive in all structures, whose lines of thrust lie *below* the deciding triangle; *negative* in all structures, whose lines of thrust lie *inside or above* the deciding triangle; *zero* in all structures, whose lines of thrust *coincide* with the side $A\,C$ of the deciding triangle.

The *sign of* b depends upon the value of g_m. The value of g_m will be:

(1) When the line of thrust lies *above* the deciding triangle

$$g_m < x_m$$

and

$$b = (g_m - g_2)\frac{x_m}{g_m} < 1$$

or *negative*, g_2 being necessarily, according to the premises, greater than x_m.

(2) When the line of thrust *coincides* with the line $D\,C$ of the deciding triangle

$$g_m = x_m$$

and

$$b = (x_m - g_2) < 1$$

or *negative*.

b is still negative, but independent of the form of the line of thrust g_m, depending only upon the way of loading g_2.

(3) When the line of thrust lies *inside*, the deciding triangle

$$x_m < g_m < \frac{l}{2}$$

and

$$b = \frac{x_m}{g_m}(g_m - g_2) \gtrless 1$$

accordingly as:

$$g_2 \lessgtr g_m$$

b is positive or negative accordingly as g_2 is smaller or greater than g_m.

(4) When the line of thrust lies below the deciding triangle

$$\frac{l}{2} < g_m < l$$

and

$$b = \frac{x_m}{g_m}(g_m - g_2) > 1$$

or *positive*, as g_2 always is smaller than $\frac{l}{2}$

(5) When the line of thrust *coincides* with *the side* $A\ C$ of the deciding triangle

$$g_m = \frac{l}{2}$$

and

$$b = \frac{x_m}{\frac{l}{2}}\left(\frac{l}{2} - g_2\right)$$

or *positive.*

(6) When the line of thrust *coincides* with the X axis

$$g_m = l$$

and

$$b = \frac{x_m}{l}(l - g_2)$$

or *positive.*

In both cases, when the line of thrust coincides with the side $A\ C$ of the deciding triangle, or with the X axis, b is *positive*, but

depending only upon the way of loading, and no more upon the form of the line of thrust.

(7) When the line of thrust lies *below* the X axis, y is then *negative* and the expression

$$b = \left(x - g_2 \frac{2fx + ly}{2fl}\right)_m = \left[\left(1 - \frac{g_2}{l}\right) x - \frac{y\, g_2}{2f}\right]_m$$

shows that b always is *positive*.

Resuming we have:

(1) The line of thrust lies *above* the deciding triangle.

a . b . c are *negative*.

(2) The line of thrust lies *inside* the deciding triangle.

a is *positive*.

b *positive* or *negative*, accordingly as

$$g_2 \lessgtr g_m$$

c *negative*.

(3) The line of thrust lies *below* the deciding triangle.

a . b . c are *positive*.

(4) The line of thrust (or points of it) *coincides* with the side $D\ C$ of the deciding triangle.

$$a = o$$

b. c. *negative*.

(5) The line of thrust (or points of it) *coincides* with the side $A\ C$ of the deciding triangle.

a . b . *positive*

$$c = o.$$

These results, which are completely independent of the way of loading or the value of the loads, show that *the signs of a b c are decided, regardless* to *the form of the line of thrust and the way of loading, only and solely by the position of the line of thrust, with regard to the deciding triangle, in all cases but for structures, of which the lines of thrust lie inside the deciding triangle.* In the latter structures the sign of b, *but only of* b, depends upon the form (g_m) of the line of thrust and the way of loading (g_2). The total value of the moments depends thus principally upon the position of the line of thrust with regard to the deciding triangle, the absolute value of $a\ b\ c$ and of the loads $G_1\ G_2\ G_3$ having only an influence upon the numeric value of M.

These results show that, whatever be the way of loading or the numeric value of the loads, I can produce in any point of a structure, with exception of the joints, either positive or negative moments, whose absolute values will lie between $+\infty$ and $-\infty$, in selecting accordingly the position of the line of thrust with regard to the deciding triangle.

In any point x_m y_m of a structure the value of M, for $y = -\infty$ becomes $+\infty$. The line of thrust is concave against the X axis, lying below the X axis. With decreasing concavity of the line of thrust, the value of M is decreasing until $y = o$. Then the line of thrust begins to lie above the X axis. It is also concave against the X axis, but with increasing concavity, the value of M decreases, until for a line of thrust, *inside the deciding triangle, the value of M becomes zero.* If the line of thrust is then made more and more concave against the X axis the value of M will begin to become negative and grow negatively with increasing concavity of the line of thrust until for $y = +\infty$ M reaches the value of $-\infty$.

That the lines of thrust corresponding to $M = o$ must all lie *inside* the deciding triangle, whatever be the way of loading or the numeric value of the loads, will be readily understood, if we mind, that only for lines of thrust lying *inside* the deciding triangle b and c can become negative, while a is positive and consequently $M = o$.

The exact form of the line of thrust depends, of course, in each case upon the absolute value of $a\ b\ c$ and $G_1\ G_2\ G_3$, and also, for the forms of the lines of thrust lying *inside* the deciding triangle upon the way of loading. For these forms inside the deciding triangle, a is positive, c negative and b either positive or negative, and it is evident that for any of these forms of the lines of thrust, a combination of loads can be found, making M to zero, but on the other side, it is also evident, that every position or numeric value of the loads, will command its own special form of the line of thrust, corresponding to the value $M = o$.

As we will see later the forms of the lines of thrust corresponding to the value $M = o$ are practically the most valuable ones.

These investigations give the means on hand to decide the signs of $a\ b\ c$ for any form of the line of thrust, but for structures, of which the lines of thrust lie *inside the deciding* triangle.

In these structures the sign of b is either positive or negative, and it remains to show how in this case also the sign of b can be defined.

To that effect $A\ B\ C$ represent in *Fig. 10* the line of thrust of a jointed bow girder, lying *inside* the deciding triangle, with g_m answering the point $x_m\ y_m$ under consideration.

I will now suppose that the sum G_2 of all the loads covering the structure from x_m to the top joint C, be decomposed into its elements $p\ p'\ p''\ p'''\ \ldots\ldots\ p^n,\ p^{n+1},\ \ldots\ldots\ p^r$, and that $\pi, \pi', \pi'', \pi''' \ldots\ldots \pi^n, -\pi^{n+1} \ldots\ldots \pi^r$ be the corresponding g_2; $p, p', p''\ \ldots\ldots$ having any numeric value and being distributed over the part corresponding to G_2 in any quite arbitrary way. I shall then furthermore assume, that:

$$\pi^n \leqq g_m \text{ and } \pi^{n+1} \geqq g_m.$$

It will then be:

$$G_2\,(g_m - g_2)\,\frac{x_m}{g_m} = \frac{x_m}{g_m}\,[p\,(g_m - \pi) + p'\,(g_m - \pi') +$$

$$+ \ldots\ldots p^n\,(g_m - \pi^n) + p^{n+1}\,(g_m - \pi^n) + \ldots\ldots p^r\,(g_m - \pi^r)]$$

and

$$p\,(g_m - \pi)$$

represents the *increment of* $G_2\,(g_m - g_2)$ from point to point.

This increment is positive as long as:

$$\pi < g_m$$

that is, until the loads cover the structure from x_m to g_m.

The next increment must be negative, as

$$\pi^{n+1} > g_m.$$

Hence:

$$\Sigma\,[p\,(g_m - \pi)]\,\frac{x_m}{g_m} = G_2\,(g_m - g_2)\,\frac{x_m}{g_m}$$

will be positive and increase until the loads cover the girder from x_m to g_m and

$$G_2\,(g_m - g_2)\,\frac{x_m}{g_m}$$

will thus reach a positive maximum, when the structure is covered with loads from x_m *to* g_m, *regardless to the way of loading or the numeric value of the loads.*

The ordinate corresponding to g_m is the parting line of the positive and negative increments of

$$G_2 (g_m - g_2) \frac{x_m}{g_m}.$$

I shall call henceforth g_m "*the maximum line of* G_2."

The ordinates y and f, on the other hand, are parting lines of the loads.

$g_m - a$, as defined above, *is the length from* x_m to *the top joint*, which must be covered with loads, *to make*

$$G_2 (g_m - g_2) \frac{x_m}{g_m}$$

to a positive maximum. g_m represents thus *not* the length from x_m to the top joint, *answering positive values of*

$$G_2 (g_m - g_2) \frac{x_m}{g_m}.$$

The latter length is quite different from g_m, depending of the way of loading, whilst g_m is only and solely depending upon the form of the line of thrust. g_m does not decide the sign of b absolutely as the signs of a and c are decided; but g_m, as defined above, gives the length from x_m to the top joint, which must be covered with loads to reach a *maximum* of

$$G_2 (g_m - g_2) \frac{x_m}{g_m}$$

and in this respect answers the purpose of defining the position of the loads creating the maximal or minimal values of M.

With this we can decide for any form of the line of thrust the action and the influence of each of the factors making up the total value of M, upon this value, and I can thus proceed now to show how the positions of the loads creating the maximal and minimal values of M are found.

The way is simple.

As the total value of M consists of a sum of single factors, of which the absolute values and signs can be decided by means of the previous investigations, for any form of the line of thrust and kind of loading, we will evidently find the maximal value of M, in making the positive factors as great as possible, the negative fac-

tors as small as possible and *vice versa* for a minimal value of M, or, in other words:

"To find the maximal value of the moments, calculate or construct a . b c and g_m, the maximum line of G_2, and fill those parts of the structure, corresponding to *positive* values of $a\,b\,c$ with loads, in selecting for $G_1\,G_2\,G_3$, the greatest values possible, and *vice versa* for the minimal value of M."

This rule is very simple and easy to apply. From it follows that in all structures whose lines of thrust lie *outside* the deciding triangle, including the sides $A\,C$ and $D\,C$ of the latter, the *maximum* of the moments is reached, by covering the structure *completely* with loads as shown in *Fig. 11*, of course, only for those points of the structure lying above and below the deciding triangle ($D\,C$).

In structures, whose lines of thrust lie *inside* the deciding triangle the *maximum* of M is reached in filling the spaces corresponding to a and g_m, and leaving $\left(\frac{l}{2} - g_m\right)$ and c empty as shown in *Fig. 12*.

In all cases the greatest possible values of $G_1\,G_2\,G_3$ being selected for the maximum of M.

The minimum of M is found in filling in the inverse sense the structure, as shown in *Fig. 13* and *Fig. 14*.

Should the line of thrust have more than *one* point of contact with a parallel to $A\,C$, or $B\,C$ in each half bow, the structure would be decomposed in parts corresponding to the number of points of contact. For instance, in *Fig. 15* in four parts ($\overline{G_1\,G_2}$ — G_3 — G_4) and

Eq. (I) would take the form:

$$M_m = a\,G_1 g_1 + b\,G_2 + c\,G_3 + d\,G_4 + e\,G_5\,(l - g_3).$$

But it will present no difficulty to apply the above-shown methods, and to deduct the correct positions of the loads inducing the maximal and minimal values M.

The rules derived for loads at rest for the alterations of the values of M from point to point in the structure can also be applied to the above defined positions inducing the maximal and minimal values of M, each position being considered as a position of loads at rest. We will find in this way the envelop of all the

curves of the moments, and the *absolute greatest and smallest values of M*, and the point in the structure in which they occur.

In first line it is visible that these absolute maxima and minima of the moments must also comply with the equation $S_m = o$, or,

$$o = \frac{f}{\frac{l}{2}} \cdot \frac{-G_1 g_1 + G_2 (l - g_2) + G_3 (l - g_3)}{G_1 g_1 + G_2 g_2 + G_3 g_3} - tng\ \mu_m$$

and if the line of thrust has only one point of contact with a parallel to $B\ C$ or $A\ C$ in each half bow, the only point answering the above conditions will be:

$$tng\ \mu_m = tng\ \frac{f}{\frac{l}{2}} = tng\ \mu_f$$

if we set apart the possibility of values from special loadings.

If I construct thus a parallel to $A\ C$ or $B\ C$, I shall have in the point of contact of this line with the line of thrust the point, in which the absolute maximum or minimum of M takes place. This point fixed, it will be only necessary to apply to it the method for defining the positions of the loads creating the maximum or minimum values of M, to decide the position of the loads generating the absolute maximum or minimum. In *Fig. 16* is shown the application for a line of thrust lying inside the deciding triangle, as in structures with lines of thrust lying outside the deciding triangle, the point in which the absolute maximum or minimum occurs, can only be defined, the position of the loads creating the maximum, being a fully loaded girder for all points.

The result is in so far curious, as it shows that the absolute maximal and minimal values of the moments in a girder under the assumed conditions, which are those met in practice, will occur in the point of contact of a parallel to $A\ C$ or $B\ C$ with the line of thrust, a point which depends only and solely upon the form of the line of thrust.

In reversing the above deducted methods, it will also be very easy to find the point in which the maximum or minimum of the moments occurs for any given loading.

Other points of absolute maximal or minimal values of M may occur from special loadings, yet they cannot be pointed out *a priori*, but will always easily be found for any specified loading.

Should the line of thrust have more than one point of contact with a parallel to $A\ C$ or $B\ C$, only the comparison of the different numeric values of the maxima and minima will give the absolute maximum or minimum of M.

SHEARING FORCES.

Loads at rest.—As we know $S = o$ gives the points corresponding to maximal and minimal values of M, $M = o$ will thus give the points corresponding to maximal and minimal values of S and the general course of the shearing forces from point to point in the structure is as follows:

The shearing forces have maxima and minima in the abutment and top joints and between these joints as many more as there are points, in which the equation $M = o$ is fulfilled, passing between two of these values each time through zero in the points corresponding to:

$$o = \frac{f}{\frac{l}{2}} \frac{-G_1 g_1 + G_2 (l - g_2) + G_3 (l - g_3)}{G_1 g_1 + G_2 g_2 + G_3 g_3} - tng\ \mu_m \quad (9)$$

In using the values of S as ordinates, the variations of S from point to point in the structure can also be graphically represented.

Fig. 17 shows the general aspect of the curve of the shearing forces, when the line of thrust has only one point of contact with a parallel to $A\ C$ or $B\ C$ in each half bow and the loads are *equally* distributed over the girder.

Should the line of thrust have more than *one* point of contact with a parallel to $B\ C$ or $A\ C$, the above curve would consist of as many parts, as there are values making S to zero.

MOVING LOADS.

We have:

$$S_m = -G_1 g_1 \left(\frac{1}{l} + \frac{tng\ \mu_x}{2f}\right)_m + G_2 \left[1 - g_2 \left(\frac{1}{l} + \frac{tng\ \mu_x}{2f}\right)\right]_m +$$

$$+ G_3 (l - G_3) \left(\frac{1}{l} - \frac{tng\ \mu_x}{2f}\right)_m$$

In introducing the same denominations as for the moments, we shall have:

$$(a_s)_m = \left(\frac{1}{l} + \frac{tng\ \mu_x}{2f}\right)_m = \left(\frac{tng\ \mu_f + tng\ \mu_x}{2f}\right)_m \quad (14)$$

$$(b_s)_m = \left[1 - g_2\left(\frac{1}{l} + \frac{tng\ \mu_x}{2f}\right)\right]_m = \left(1 - g_2\ \frac{tng\ \mu_f + tng\ \mu_x}{2f}\right)_m \quad (15)$$

$$(c_s)_m = \left(\frac{1}{l} - \frac{tng\ \mu_x}{2f}\right)_m = \left(\frac{tng\ \mu_f - tng\ \mu_x}{2f}\right)_m \quad (16)$$

which values are obtained in writing

$$\frac{f}{\frac{l}{2}} = tng\ \mu_f$$

The coefficient b can also be expressed in this case by introducing an auxiliary quantity making the value of b to zero.

$$g_2 = g_s = \left(\frac{2f}{tng\ \mu_f + tng\ \mu_x}\right)_m \quad (II^c)$$

g_s as g_m can easily be constructed.

g_s is the abscissa of the point of intersection of a parallel through A to the tangent in the point $x_m\ y_m$ of the line of thrust, with the line $B\ D$, the upper side of the deciding triangle as shown in *Fig. 19*.

The demonstration follows from the figure.

In introducing these values we have the following *three* forms of S_m:

$$S_m = a_s\ G_1 g_1 + b_s\ G_2 + c_s\ G_3\ (l - g_3) \quad (II)$$

$$S_m = -\ G_1\ g_1\left(\frac{tng\ \mu_f + tng\ \mu_x}{2f}\right)_m + G_2\left(1 -\right.$$

$$\left. - g_2\ \frac{tng\ \mu_f + tng\ \mu_x}{2f}\right)_m + G_3\ (l - g_3)\left(\frac{tng\ \mu_f - tng\ \mu_x}{2f}\right)_m \quad (II^a)$$

$$S_m = -\ \frac{1}{g_s} G_1 g_1 + G_2 (g_s - g_2)\frac{1}{g_s} + G_3\ (l - g_3)\left(\frac{2g_s - l}{l}\right)\frac{1}{g_s} \quad (II^b)$$

The value g_s has the same properties with regard to S as g_m with regard to M.

The ordinate of g_s is the parting line of the positive and negative increments of $G_2 (g_s - g_2) \frac{1}{g_s}$ and the second member of eq. (II) will thus reach a *positive maximum*, when the loads cover the structure from x_m to g_s *regardless to the numeric value of the loads or the way of loading*. The demonstration is exactly the same as for g_m of the moments.

I shall call henceforth g_s *the maximum line of* G_2.

g_s as defined above gives the length from x_m to the top joint, which must be covered with loads to reach a positive maximum of $G_2 (g_s - g_2) \frac{1}{g_s}$ and answers thus, as g_m for the moments, the purpose of defining the position of the loads creating the maximal and minimal values of S_m.

If we consider now Eq. (II) we see that the total value of the shearing forces depends of the *same two factors* G_1 G_2 G_3 and a b c as the total value of the moments, these factors expressing in Eq. (II) exactly *in the same way the influence of the loads and of the form of the line of thrust with regard to the total value of the shearing forces*, as they do in eq. (I) with regard to the total value of the moments, differing only in their absolute value. The results of the investigations for defining the positions of the maximal and minimal values of the moments will thus be directly applicable to the shearing forces, and I have only to show how the signs of a b c can be defined for any form of the line thrust.

If we consider to that effect eq. (II) we see that the signs of a b c depend merely of the *value of* $tng\ \mu_m$.

If $tng\ \mu_m$ *is positive:*

a is negative, b has a positive maximum and c is positive or negative, accordingly as:

$$tng\ \mu_m \lessgtr tng\ \mu_f$$

If $tng\ \mu_m$ *is negative:*

a is positive or negative accordingly as:

$$tng\ \mu_m \gtrless tng\ \mu_f$$

b has a positive maximum or is positive, and c is positive.

These rules will give in every instance the correct sign of $a\ b\ c$, as it will always be very easy to decide whether $tng\ \mu_m \gtrless tng_f$, μ_f being the angle between $A\ C$ or $B\ C$ and the X axis.

With this we can decide for any form of the line of thrust the action and the influence of the factors composing the total value of S, upon this value, and we shall find now the positions of the loads inducing the maximal and minimal values of S in the same way as for the moments, to wit:

"To find the maximal value of the shearing forces, calculate or construct $a\ b\ c$ and g_s the maximum line of G_s, and fill those parts of the structure corresponding to positive values of $a\ b\ c$ with loads, in selecting for $G_1\ G_2\ G_3$ the greatest values possible, and *vice versa*, for the minimal values of S."

Fig. 19 shows the application of this rule for a positive value of $tng\ \mu_m$, when $tng\ \mu_m > tng\ \mu_f$; a and c are then negative and only the positive maximum of G_2 is positive.

Fig. 20 shows the application also for a positive value of $tng\ \mu_m$, but $tng\ \mu_m < tng\ \mu_f$.

$-a$ is then negative, $b > \frac{l}{2}$ and c positive.

Should the line of thrust have more than *one* point of contact with a parallel to $A\ C$ or $B\ C$ in each half bow, the structure would be decomposed in parts corresponding to the number of points of contact, and eq. (11) take the form:

$$S_m = (a_s)_m\ G_1\ g_1 + (b_s)_m\ G_2 + (c_s)_m\ G_3 + \ldots . (p_s)_m\ G_3(l - g_3).$$

But it will present no difficulty in applying the above deducted rules to find in this case also the correct positions of the loads inducing the maximal and minimal values of S.

For special loadings, moreover, other maximal and minimal values of S can occur, but it will always be possible to define them easily for a specified loading.

With this, the positions of the loads inducing the maximal and minimal values of the moments and shearing forces can be defined in all instances in a very simple manner, as soon as I have explained how the point into consideration $x_m\ y_m$ goes into the parts G_1 or G_2.

In considering eq. (4)

$$M_m = Q\,x_m - G_1\,(x_m - g_1) - H\,y_m$$

we see that:

"The point under consideration $x_m\,y_m$ forms a part of the first division G_1, while the top joint belongs to the third division G_3." (See *Fig. 21.*)

Different from this is the division of the loads for the shearing forces. From equation:

$$S_m = V_m - H\,tng\,\mu_m = Q - G_1 - H\,tng\,\mu_m \qquad (6)$$

follows, that:

"The point under consideration $x_m\ y_m$ forms a part of the *second* division G_2, while the top joint belongs to the third division G_3." (See *Fig. 22.*)

I shall henceforth represent, when necessary, the divisions G_1 G_2 G_3 as shown in (*b*) *without* always adding the form of the line of thrust (*a*).

Now S is the increment per unit of length of M. The above rule gives us thus the means on hand *to express correctly the actions of the difference (algebraically) of two moments.* I will show this more clearly yet in expressing S as the difference of two values of M.

Using eq. (I^a), we have:

$$M_m - M_{m-1} = \frac{\zeta'_m - \zeta'_{m-1} - (y_m - y_{m-1})}{2f}\,[(G_1 g_1)_m - (G_1 g_1)_{m-1}] +$$

$$+ [(G_2)_m - (G_2)_{m-1}]\left[(x_m - x_{m-1}) - [(g_2)_m - (g_2)_{m-1}] \times\right.$$

$$\left.\times\,\frac{\zeta_m - \zeta_{m-1} + (y_m - y_{m-1})}{2f}\right] + [G_3\,(l - g_3)_m - G_3\,(l - g_3)_{m-1}] \times$$

$$\times\left[\frac{\zeta_m - \zeta_{m-1} - (y_m - y_{m-1})}{2f}\right]$$

dividing by Δx_m and writing, see *Fig. 23.*

$$\frac{\zeta'_m - \zeta'_{m-1}}{\Delta x_m} = -\,tng\,\mu_1;$$

$$\frac{\zeta_m - \zeta_{m-1}}{\Delta x_m} = tng\,\mu_1$$

$$\frac{y_m - y_{m-1}}{\Delta x_m} = tng\,\mu_m$$

Fig. 3.

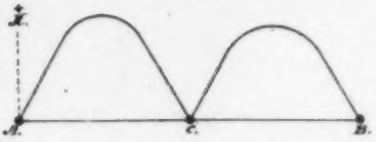
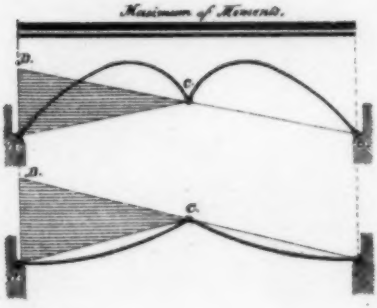
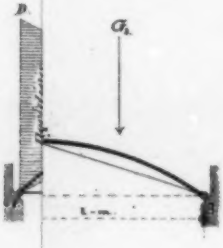


Fig. 11.

Maximum of Moments.





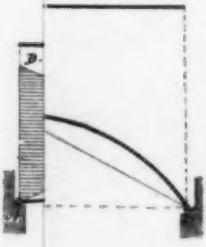


Fig. 17.

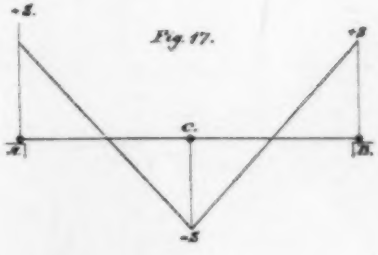
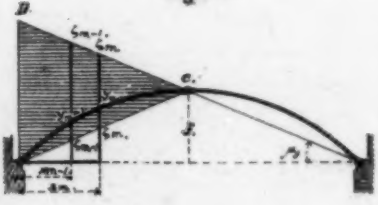


Fig. 23.



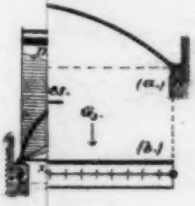


Fig. 1.

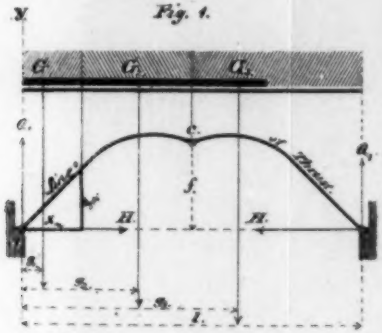


Fig. 2.

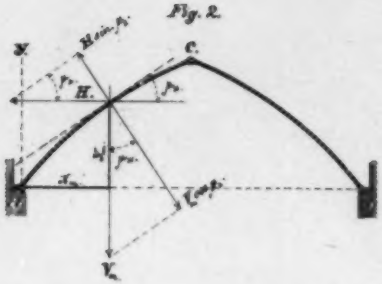


Fig. 6.

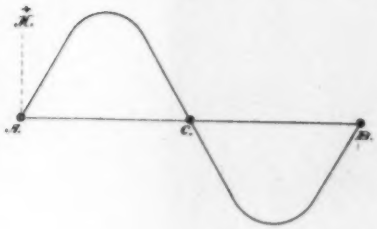


Fig. 7.

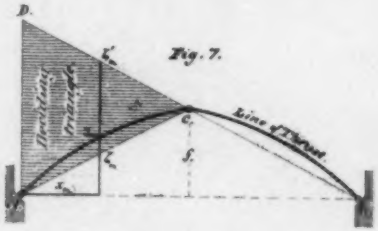
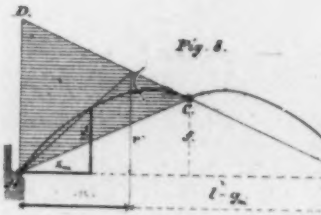


Fig. 8.



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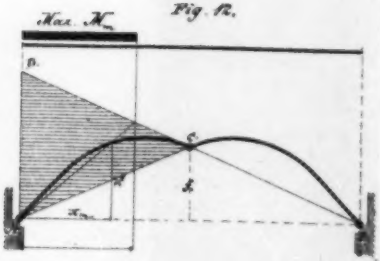
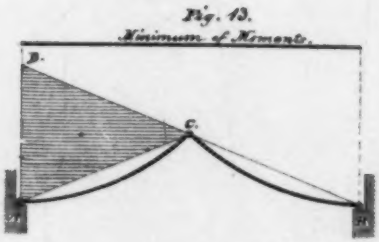


Fig. 13.



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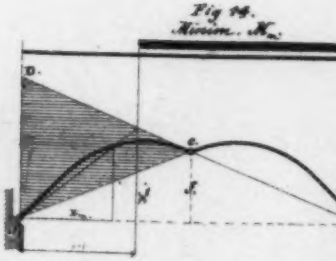

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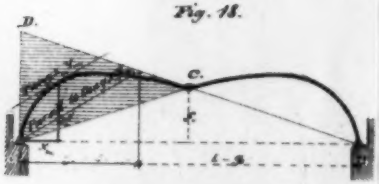
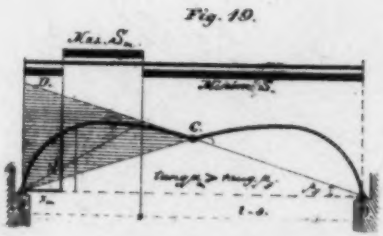


Fig. 19.



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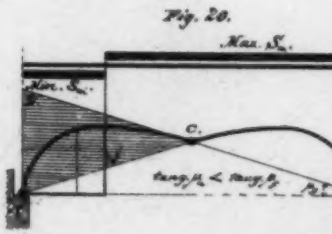


Fig. 3.

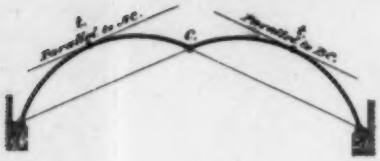


Fig. 4.

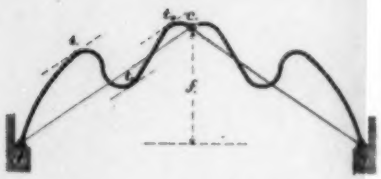
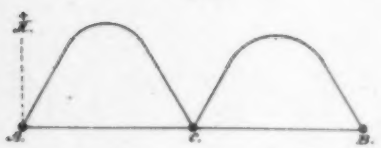


Fig. 5.



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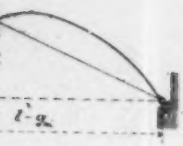

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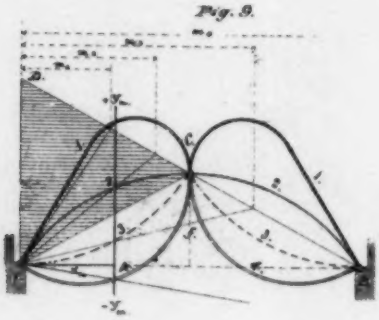


Fig. 10.

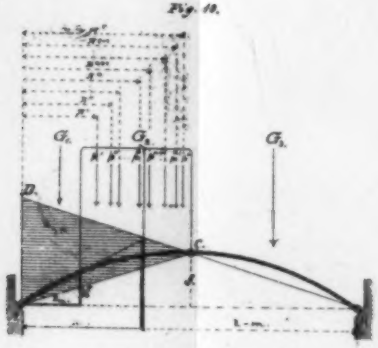


Fig. 11.

Maximum of Moments.

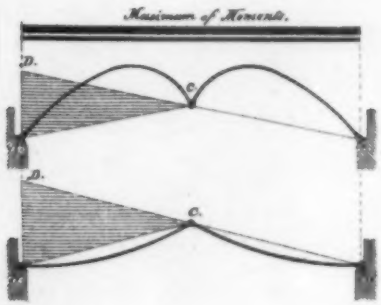


Fig. 14.

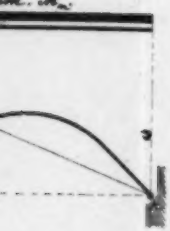


Fig. 15.

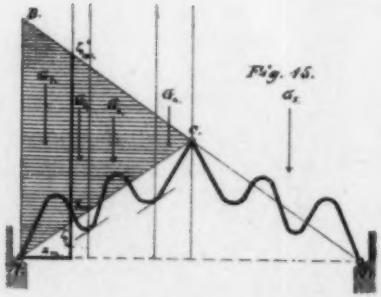


Fig. 16.

Abs. Maxim. of M.

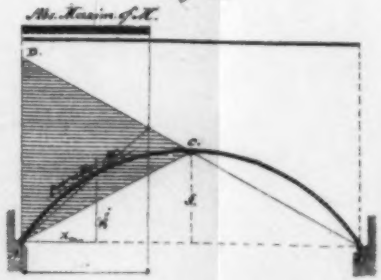


Fig. 17.

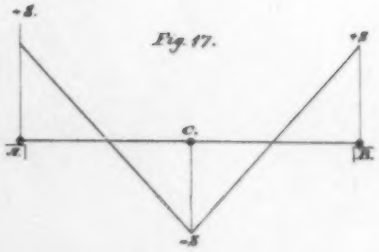
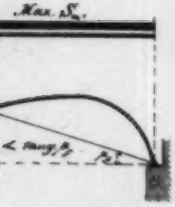


Fig. 20.



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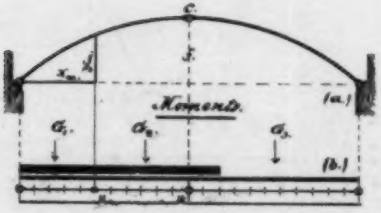
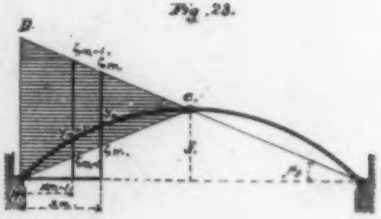


Fig. 22.

Fig. 23.



this equation gives:

$$\frac{M_m - M_{m-1}}{\Delta x_m} = S_m = -\frac{tng\,\mu_f + tng\,\mu_m}{2f}\,[(G_1\,g_1)_m - (G_1\,g_1)_{m-1}] +$$

$$+\,[(G_2)_m - (G_2)_{m-1}]\left[1 - [(g_2)_m - (g_2)_{m-1}]\,\frac{tng\;\mu_f + tng\;\mu_m}{2f}\right] +$$

$$+\,[G_3\,(l - g_3)_m - G_3\,(l - g_3)_{m-1}]\,\frac{tng\;\mu_f - tng\;\mu_m}{2f}$$

In comparing the last equation, with eq. (II^a), we see that $a\,b\,c$ of course have the same values, as they express simply geometrical properties, and are completely independent of the way of loading, but the action of $G_1\,G_2\,G_3$ appears as the difference of the two values of M, and the correct action of this difference could not be defined, *without* the above rule for shearing forces.

The above rule for defining the correct division of $G_1\,G_2\,G_3$ of the shearing forces is thus of the greatest importance. It gives, *as long as we add or deduct only the values of two moments, the correct action, or the correct division of* $G_1\,G_2\,G_3$ *in the girder*, in transforming the value of S into that of M, or *vice versa*, and allows in this way the substitution of one force for the other.

Beside the division of $G_1\,G_2\,G_3$, the correct position of the loads making the moments or the shearing forces to maxima or minima, depends also upon the greatest value of $G_1\,G_2\,G_3$ possible. But as this point can much better be explained with the expressions of the internal forces, I will leave it until these expressions are developed, and turn now to the development of the equations of the internal forces.

(*To be continued.*)

CORRESPONDENCE.

THE IMPROVEMENT OF SABINE PASS.

The Committee on Publications of the FRANKLIN INSTITUTE.

WASHINGTON, D. C., April 9, 1888.

Gentlemen :—I see on perusing your April number that Prof. Haupt in his discussion on "Jetties for Improving Estuaries" has made use of some mis-information in reference to the Sabine Pass, Louisiana and Texas. He states that the west jetty (which was the one first commenced, neither being as yet *built*) made a shoal on its east side. Now the fact is, that the partially-constructed west jetty had in 1885, the date he mentions in his article, caused quite extensive deepening and scour on its east side; the curve of eighteen feet depth inside the bar had moved outward 600 feet, and that on the outside of the bar had moved shoreward from 200 to 1,100 feet, so that the distance between this curve of depth on the inside and on the outside had decreased 1,600 feet; the curve of nine feet depth on the inner side of the bar had moved outward 2,150 feet, and that on the outer side had changed but little; the channel of six feet depth had increased in least width from 550 feet, according to the 1881 survey, to 2,300 feet at that time, 1885. All these facts were exhibited on the page of the official report under Prof. Haupt's eye when he wrote.

On this same page of the official report, it was shown that the nine-feet curve to the *westward* of the jetty had advanced between 700 and 1,100 feet, and the six-feet curve inside the *Clifton* (a war wreck) had been obliterated by deposits, while outside that wreck this curve had advanced 2,700 feet. The fact is that the west jetty had caused immense shoaling on *its western side*, as could be seen by the 1884 and the 1885 reports.

Very respectfully your obedient servant,

THOMAS TURTLE, *Captain of Engineers.*

To the Committee on Publications of the FRANKLIN INSTITUTE JOURNAL:

Gentlemen :—In reply to the above criticism I beg leave to submit that from the manner in which the criticism is made, and especially in the allusion to the exhibit of facts "under my eye when I wrote," it would seem to question the veracity of my statements. I respectfully submit, therefore, the following, as the paragraph alluded to by Capt. Turtle. I say in the paper on jetties: "At Sabine Pass, estimated to cost $3,177,606.50, the *west* jetty was built first and made a shoal on its east side, and in 1885 the crest of the bar had been moved seaward 1,900 feet, and it is said 'it is perhaps impossible to

decide as to the amount of influence the work done has had upon the depth of water across the bar.'"

All of the above are facts as gleaned from the official report of the Chief of Engineers, and they are the important facts in this case. Capt. Turtle appears to attach great importance to the movement of the contour lines and the enlargement of the inner basin, which is merely a natural consequence of the obstruction produced by the jetties and contraction of the ebb, whereby a reaction is produced, which tends to deepen the channel in the Pass and push the bar further seaward, as stated by the assistant in charge of the surveys.

Permit me to quote a few extracts from the history of this improvement: "In 1873, a channel twelve feet deep was dredged across the bar; another was dredged in 1880; both soon refilled." * * * "The work was commenced in 1883 (January 1), and in 177 working days in that year 118,552 cubic yards of jetty were laid, embracing a total length of 16,074 feet of the foundation of the west jetty; 6,146 feet of which, from the shore end, was built nearly or quite up to the level of mean high water." Work was then stopped in consequence of the expenditure of the appropriation until after July 5, 1884, "when a survey and examination was made by and under the direction of Capt. Turtle," who made a report suggesting "a new line differing somewhat from the originally proposed line of the east jetty."

I think, therefore, that there is no doubt but that the *west* jetty was built first (I did not say completed). It was in existence for a distance of over three miles from shore (over one mile reaching nearly to mean high water) for over a year before the east jetty was commenced as shown from the following: "Work was commenced on the east jetty in March, 1885, and on June 30, 1885, the foundation course was laid for a distance of 10,200 feet from shore and 8,825 feet of this jetty extending out from the shore was built up to mean high water level." "The contractors will probably finish their work in August of this year (1885.") * * * "The portions of the jetties thus far built have produced no material changes in the depth of water on the bar, nor at this stage of the work were any decidedly favorable changes to be expected." * * * "When the two jetties are built up high to the outer crest of the bar, then a scour may reasonably be looked for; should the expected scour not occur, then resort would be had to the dredge." These extracts are from the report of Major Heuer.

Again, the figures stated in Capt. Turtle's letter are those taken from the report of Assistant Engineer Raymond, and based upon a survey made in August, 1884, or prior to the beginning of work upon the east jetty, so that the changes produced were those due to the west jetty only, and in stating what these changes were, Mr. Raymond says:

"The line of deepest water over the bar has moved somewhat to the eastward by the formation of a shoal opposite the *Clifton*,* and extending from the jetty 1,000 feet east, upon which the depth has decreased from 0·6 to 1·3 feet since 1881."

* Which is on the line of the west jetty.—L. M. H.

The curves referred to, as drawn in red upon the comparative chart submitted, are not shown in the report, so that the map gives no very definite information as to relative changes.

He adds: "The extent and position of the sand deposit would seem to leave but little doubt as to its origin. As shown upon the chart by the dotted area,* it lies almost entirely upon the east side of the west jetty, the small deposit to the westward having been probably carried over the top of the jetty. The main deposit extends to the eastward to a point nearly on the prolongation of the six-foot curve on the east side. Its width is greatest near the jetty and diminishes as it extends to the eastward until it finally disappears."

Mr. Raymond also adds in concluding his report:

"The strong currents due to the extreme high water of last spring having deepened the channel above the jetty, where the work cannot be claimed to have had any effect, it is perhaps impossible to decide as to the amount of influence the work done has had upon the depth of water across the bar. The greatly increased width of the nine-foot channel and its prolongation so far down stream might fairly be attributed to some extent to the narrower water way produced by the jetty." * * * "The crest of the bar, as determined by a line joining the points of the six-foot curve nearest together, has advanced into the Gulf 1,900 feet."

The changes then above the bar, according to the Assistant Engineer, were produced by extreme high water and the contraction of the ebb stream, producing a reaction in the throat of the Pass, and the beneficial results in deepening the water, are incapable of being determined. The crest has also moved gulfward, as I have stated, unless the reports themselves are misleading.

As to the "immense shoaling on *its western side*," it is easily explained. The jetty was submerged at that date for a length of over two (2) miles, the sand carried westward by the "flood component" as well as that coming down the Pass, was rolled over the jetty and deposited in the groin formed by the jetty and shore which was its natural depository. It built its own ramp to the eastward of the jetty and was then readily carried over it by the flood. If a survey were made to-day it would doubtless show a similar slope to eastward of the east jetty over which the sand is prevented from climbing only by its being extended to or above high water, but it will ultimately creep around the end as the angle fills up.

I have respectfully to submit, therefore, that the extracts contained in my paper on "Jetties for Improving Estuaries" do not misstate or misrepresent the facts in the case, unless I read them incorrectly; if otherwise, I should be pleased to make the necessary acknowledgements.

Very respectfully, your obedient servant,

LEWIS M. HAUPT.

UNIVERSITY OF PENNSYLVANIA,
PHILADELPHIA, *April 21, 1888.*

* This is not shown in the reproduced chart accompanying reports in my possession.—L. M. H.

DOWNWARD-DRAUGHT FURNACES.

The JOURNAL OF THE FRANKLIN INSTITUTE for February, 1888, contains an article by Mr. Francis E. Galloupe, purporting to be a supplement to the investigation of Lozano and Erben upon downward-draught furnaces published in the JOURNAL for November and December, 1887.

The article is mainly an attempt to discredit the record of the experiments made at 94 Liberty Street, New York, by trying to show from our account of the experiments that some points necessary to the carrying out of the details of the tests in a proper manner seem to have been overlooked; and of a report of a ten-hour boiler test in East Somerville, Mass., totally irrelevant to the investigation it assumes to supplement.

Mr. Galloupe finds fault on the following points:

(1) Large percentages of refuse from the coal.

(2) Percentages of unburned coal, which must have parted with some of its calorific power if put in the furnace at all, different in the two trials.

(3) Variations of water level.

(4) Absence of correction for one-half inch too high water-level in the boiler at the end of the second test.

I shall briefly take up those points in their order.

(1) The total weight of refuse per pound of coal put into the furnace was in the first test ·271,066 pound, and in the second test ·269,230 pound. As long as this was practically the same, it does not make a particle of difference in the conclusions to be derived from the comparison of the results of those competitive tests, whether the percentage was large or small.

(2) The way to get the approximate weight of that part of the coal, other than ashes, which escaped unburned, is to subtract from the total weight of the refuse the weight of real ashes in the coal as determined by analysis. Thus, the total weight of unburned carbon per pound of coal put into the furnace is seen to have been ·172,566 pounds in the first test, and ·170,730 in the second, the discrimination complained of being well nigh infinitesimal, and certainly within the limits of the unavoidable errors of observation. Mr. Galloupe used the wrong figures, taking for unburned coal only that which was picked from the ashes.

(3) The height of the water in the glass gauge was, as reported:

	Test with Ordinary Grate. Inches.	*Test with Downward-Draught Attachment, Inches.*
Lowest,	1	1·5
Highest,	4	4·5
Mean during the tests,	2·84	3·23

a difference of ·39 inch in the mean height.

(4). One-half inch of water in a boiler 14 feet long, 5 feet in diameter, amounts to less than 182 pounds; 182 pounds of water heated from the temperature of the feed to the steam temperature at which the trial was ended, means 31,122 British thermal units, to impart which at the efficiency found, would require only 3·74 pounds of the coal; or, in other words, the correction desired would be only about one per 1,000 of the coal used in the test. On the other hand, whereas the first test was begun and ended with steam of

precisely sixty pounds pressure, the second test was begun at sixty pounds and ended at forty-eight pounds, a drop of temperature on the total weight of the contents of the boiler, etc., of about 13° F., correction for which unavoidable fact would be in the opposite way, and somewhat greater. We were not censured for having likewise deliberately omitted this correction against the device.

Mr. Galloupe says, also, that "the admission that the water-level was left one-half inch higher at the end of the second test 'through inadvertency,' makes the feed-water record inaccurate." Singular, indeed! Nevertheless, anyone can see that the accuracy of the weight of the feed water has nothing to do with the inadvertency of the man in charge of the feed pump, or with the admission.

The superiority of the water-tube grate in regard to burning the coal up cleaner than the ordinary grate, was represented by 6·78 pounds in 3,692 pounds of coal used. We made no mention of it, because it was too small a quantity of its kind to be mentioned at all.

Really, if Mr. Galloupe can obtain from all his points, any quantity the commercial value of which is appreciable, he should compute and exhibit it.

418 W. Fifty-seventh Street, Carlos A. Lozano, M.E.
New York, *March, 1888.*

The Limiting Diameters of Describing Circles for the Teeth of Annular Wheels.

In a note relating to "the Limiting Diameters of Describing Circles for Teeth of Annular Wheels," in your issue of April, 1888, Mr. Albert K. Mansfield states that in my "Treatise on Kinematics," (1883,) I "practically claim to be the original discoverer of the law of kinematics bearing on that point"—immediately adding that he had published a demonstration of that law in your issue of January, 1877.

Mr. Mansfield apparently uses the words "original discoverer" as synonymous with "first discoverer;" whence some of your readers may have received an erroneous impression, as reference to my preface will show that I did not positively claim the credit of priority, which, in mathematical matters, it is always unsafe to do, because identical results are very often, as in this instance, independently reached by different persons.

Mr. Mansfield further says: "It would seem, in the absence of evidence to the contrary, that he was not aware of your previous publication of the matter."

Allow me to assure your readers, since he does not, that this supposition is correct—the absence of evidence is accounted for by its non-existence.

I am perfectly willing to admit that Mr. Mansfield preceded me in point of time; but I did not know of his investigation until more than four years after the publication of my treatise.

Of all which Mr. Mansfield was informed, some time previously to the appearance of his note.

C. W. MacCord.
Stevens Institute of Technology,
April 16, 1888.

BOOK NOTICES.

THERMO-DYNAMICS. De Volson Wood, C.E., M.A. New York: Burr Printing House, 1887. 12mo. pp. x. 234.

This little work, which was written by Prof. Wood for his own use in the class room, divides the general treatment of the subject into four parts, namely, general principles, perfect gases, imperfect gases, and heat engines, and also contains an appendix on the luminiferous æther, and one on the second law of thermo-dynamics.

The attempt of Prof. Wood to put into a convenient shape this subject for class room use is to be commended, but it is difficult to see that he has succeeded.

As in the examination questions after Chapter I, he says that some of these questions require knowledge outside of the text, it would appear that the ground had not been covered sufficiently to make it a good text-book. While the intricacies of the theory of thermo-dynamics are of necessity part of the education of a scientist or professor of dynamics, it hardly seems necessary to go into the matter to the same extent for students, and a statement and proof of the fundamental theories and their practical application seems to be the more desirable course. As the majority of students in after life could use the practical applications if they were fully and plainly set forth, the general knowledge obtained in a course of instruction, as above indicated, would point the way for the very few men who desire a greater knowledge of the subject.

The meaning of many terms in the work are not as distinctly stated as one might wish. The distinction between a reversible and a non-reversible cycle, as made in Art. 32, is entirely unnecessary, and according to an equally good authority (Röntgen-Du Bois), is incorrect. In Art. 26 two examples are given of re-entrant curves, and unless the author means closed curves it is hard to tell what his "re-entrant" means. While the articles on the mechanical equivalent of heat is interesting it is misleading, as the table furnished by him would lead a student to infer that the mechanical equivalent varied with the temperature. The graphical method of illustrating the amount of heat absorbed according to any law is constantly used throughout the work and tends to elucidate what to the student might otherwise seem rather obscure.

The ammonia engine (refrigerating) is dismissed with a paragraph which gives no information on the subject, while the air compressor receives about the same treatment.

The clearness of the treatment of the subject of specific heat might well have been used in other parts of the work.

The treatment of the thermo-dynamic function, Art. 97*a*, is such that one turns for relief to Rankine (Art. 244, *Steam Engine*) and if that article had been transferred bodily, one article, at least, would be much clearer. A page and a half is allotted to the condenser and no attempt is made to explain what actually takes place in it.

One of the interesting parts of the book is that which treats of cutting-off in steam engines, and the solution of the problem of the most economical point of cut-off is interesting, although incorrect.

In equation 190, page 183, we have an expression for the work done for unit of cost ($1) of steam and evidently a maximum value with reference to the ratio of expansion as a variable will give the most economical point of cut-off at which to run the engine. Looking back at the equations from which 190 is deduced, we find, as follows:

$$A\,l\,n = r\,v\,W \quad (188)$$

in which

A = area of the piston in square feet;
l = length of stroke in feet;
n = the number of times the engine takes steam in unity of time;
r = the ratio of expansion;
v = the volume of unity of weight (one pound) of steam at the pressure p_1 (= the initial absolute pressure in the cylinder per square foot);

and

W = weight of steam used by the engine in unity of time—one hour.

With the above statement of the meaning of the terms in the equation, it is evident that it is incorrect, as it is a fact well known to Prof. Wood that the weight of steam used in any engine is in excess of that necessary to just fill the volume passed through by the piston, and this fact is recognized on page 188, where he allows thirty per cent. for condensation; on page 198, where it is shown that the amount of condensation varied with the point of cut-off, and in many other cases. And as this equation is one which is used in determining the proper point of cut-off, it is clear that any point of cut-off, derived from any equation in which this enters cannot be the most economical, although "forty students" obtained results which differed but slightly. And it might be well to note here that any criterion which does not take into account the fact that the amount of condensation varies with the point of cut-off, as is plainly set forth in the results given on page 198, omits what is often a very important item in an investigation of this kind, and is of no account in determining the most economical point of cut-off. H. W. S.

A Manual of Steam Boilers, their Design, Construction and Operation. R. H. Thurston, M.A., Doc. Eng. New York: John Wiley & Sons, 1888. pp. xvi–671.

This latest work of Prof. Thurston's, as the title page announces, is for technical schools and engineers, and covers the ground stated in its title fully. Briefly, the different subjects treated of are history and classification, materials, fuels, heat, thermo-dynamics, designing, care, trials and efficiency, and explosions.

The book, as the author says, is a "larger book than could be profitably used in the average technical school," and there seems to be no reason why it could not have been made much smaller and have still covered the ground

as fully as it at present does. It has been freely padded, and the omission of many of the paragraphs, especially in the first half of the book, would have brough it into such a shape that it could have been used very well in the "average technical school." For instance, on page 253, the first six lines read: "The properties of water, as noted by the senses, are familiar to all. It occurs universally distributed throughout the world, in earth, air and sea, in its three forms, ice, water and vapor, and in its most familiar form covers three-fourths of the surface of the globe. As ice and snow it permanently covers the Arctic region and the top of lofty mountains, etc." Compilations of facts of this sort are of but little use to either a student of the "average technical school" or to an engineer, and the omission of many other passages of the same sort would have made a more useful work it. To anyone not having a copy of Prof. Thurston's previous works, the treatment of materials is all that can be desired. The subjects of heat and thermo-dynamics are treated more fully than necessary in a book of this kind. There is the same excess of words here that has already been referred to, and it is simply a waste of time to read, even on the authority of Prof. Thurston, that water is to be found in the sea, etc.

That part of the work between pages 300 and 538 treating of the design, care and testing of steam boilers, is the only part of the work which deserves a place in an engineer's library. This is by far the best series of articles on how to design a boiler, and the reasons for so doing, that has ever been presented in book form. The data given have been put into such a shape that they can be instantly used, and for this reason they are invaluable to the engineer who is not a specialist in boilers.

The publication here of the method of testing adopted by the American Society of Mechanical Engineers will tend to promote uniformity of work among those not members of the Society. The apparatus for testing boilers described, although perhaps not the best attainable for the purpose, will enable one to make accurate and satisfactory tests.

The latter part of the book, which is devoted to steam-boiler explosions, could have been nearly all omitted without injuring the character of the work.

An inspection of the engravings alone will show that while many of them might serve very well for newspaper cuts, in a volume of this sort they simply take up space. H. W. S.

USE OF BELTING FOR TRANSMISSION OF POWER. By John H. Cooper, M.E. Third Edition. Phila.: Edw. Meeks: London, E. & F. N. Spon, 1888.

It is a rare thing that a practical engineer of large experience makes a book upon the subject with which he is most fully conversant, and when made such books are too often records of mere conclusions and inferences rather than of facts; faults from which this treatise is exempt.

This work submits concisely and clearly, well-illustrated descriptions of the many devices and arrangements under which belting is used, with a careful recital of all of the conditions involved in each case, and such rules and tabulated information as naturally result from facts and tests described.

With this there is a careful compilation of pertinent matter from the works of others on the subject, in every instance duly accredited, and the whole is thoroughly well indexed.

The manner in which the earlier editions of this work were appreciated by practical men is a strong endorsement by the most competent critics upon the subject; the present edition contains much additional information and is compiled with the same conscientious care that has secured the confidence of the engineering public in all of this author's works. The book is simply invaluable as the best on the subject. S. L. W.

SCIENTIFIC NOTES AND COMMENTS.

TECHNOLOGY.

A NEW PROCESS OF PROTECTING IRON EFFECTUALLY AGAINST CORROSION.—For a period of more than ten years experiments have been made under the auspices of the Hydrogen Company of the United States to discover a simple, economical and practical method of protecting iron and steel from all ordinary corrosive influences. A large number of patents were secured and about $100,000 expended in the erection of plants at Washington, D.C., Newburg-on-the-Hudson and New York, and some of the results were of the most satisfactory character. Iron that had been treated by the processes referred to effectually resisted the action of nitro-muriatic acid and other severe tests to which it was subjected, while untreated iron was immediately attacked by the acids and quickly destroyed.

But although many of the specimens thus treated gave very satisfactory results, others proved defective, and it became apparent to the contributors to the funds that the exact conditions as regards temperature, quality and quantity of material employed, and duration of treatment had not been so accurately determined that results could be duplicated with unerring certainty; an essential condition without which no process could ever be made a commercial success.

This explanation has been considered necessary to account for the fact that an industry which promised results of such extraordinary value to the public and to the parties financially interested should have been allowed to linger until the greater portion of the life of the original patents had expired.

But persistency has at last been rewarded with success. The company succeeded in securing the services of a thoroughly practical and scientific engineer, chemist and metallurgist, Dr. Geo. W. Gesner, who was enabled to discern the defects of former treatments and to remedy them successfully by new apparatus and processes, which have recently been patented, so that while the old patents are still held by the company, they have to a great extent been superseded by more recent issues under which operations now are and will hereafter be conducted.

The former treatment consisted in placing the articles to be operated upon in a close chamber, similar to a gas retort, and when heated to a temperature

of about 1,200° F., steam superheated in a separate furnace was introduced, followed by naphtha or other hydrocarbon vapor.

The results, as previously stated, were not always uniform, and when satisfactory, could not be duplicated under former management with certainty as to the result.

All this is now changed, and the results are so uniform and certain, that with a few hours of instruction in the manipulation of the apparatus an ordinary laborer, with no technical education and with average intelligence, can secure results with entire uniformity.

Dr. Gesner soon discerned that one of the chief defects in the former treatment arose from the fact that the steam superheated in a separate furnace and conducted by pipes into the retort was invariably cooled to the extent of several hundred degrees before admission and came in contact with the heated iron at a much lower temperature.

To remedy this defect and insure absolute uniformity of temperature between the iron and the superheated steam at the instant of contact, a peculiar but very simple form of superheater was devised and inserted in the retort itself. The result was entirely satisfactory, and after a number of experiments by him to determine the conditions necessary to insure the best treatment, the works were turned over to an employé who has since operated them with uniform results.

The plant now in operation is located at East Port Chester, near the extensive foundry of Abendroth Brothers, and consists of twelve vertical retorts with a capacity for the treatment of about twenty tons per day of the Gesner sanitary soil pipe. The time required for each charge is about two hours.

THE PROCESS.

After the pipes have been lowered into the retorts by means of a traveller, the retorts are closed for about fifteen minutes until the contents are heated to the proper temperature. Steam from a boiler at sixty pounds pressure is then introduced into the superheater, which it traverses and from which it escapes at the temperature of the iron upon which it acts for about one hour. A measured quantity of some hydrocarbon is then admitted with a jet of steam, followed again by a fixing bath of superheated steam, which completes the process.

The most extraordinary feature of the operation is that, as Prof. Gesner positively asserts, there is no pressure in the retort and no free explosive gases. The water seals attached to the retorts show only slight oscillations, but not an inch of pressure, and when the covers are removed and air admitted, there is no explosion, as there always is when free hydrogen or carbonic oxide are present, and as there always was before Prof. Gesner took charge.

The absence of pressure and of explosive gases is a proof that all the operations have been so nicely regulated as regards material used, quantity and time of application, that a perfect absorption and union of the carbon, oxygen and hydrogen with the iron has been effected.

The protection thus afforded to the iron is not a mere coating, like paint,

but an actual conversion, to a greater or less depth, into a new material, just as in the process of case-hardening, iron is converted into steel. When properly treated, this material does not seem to be detachable by pounding, bending, hammering, rolling or heating. The pipes treated at Port Chester have been immersed in baths of dilute sulphuric acid and exposed to the salt air for weeks without change, while untreated pipes were quickly covered with red oxide or with sulphate of iron.

The exact chemical composition of the material produced by this treatment has not been reported upon by Prof. Gesner, but it is probably a carbide, hydride and superoxide of iron. This would seem to be a necessary result, if, as is stated, the retorts when opened contain no free gases, neither hydrogen, oxygen nor carbonic oxide. As these gases are necessarily formed, their disappearance can only be explained on the theory that they have combined with the iron forming the three compounds of superoxide, plumbago and the alloy of hydrogen and iron, for which Prof. Gesner has proposed the name of Hydron.

The plant now in operation at Port Chester has been designed simply for cast-iron soil pipe, but Prof. Gesner is preparing plans for a more extensive plant for the treatment of wrought iron and steel, to be erected at South Brooklyn.

In the application of this process each specialty will require a plant adapted to it, and a series of experiments to determine the exact conditions as to temperature, quantity, kind, duration, etc., to secure the best results, after which they can be duplicated indefinitely with any ordinary intelligence.

The question is often asked: What is the effect of this treatment upon the tensile strength of the material? This can only be answered by direct tests, but if the new material should not possess the tensile strength of the untreated iron, as in wires or rods, compensation can be secured by a slight increase in diameter. It is certain that in some specimens the treatment has increased the toughness and strength by the annealing process to which the material is subjected. Sheet iron of poor quality, that would break by bending, has been rendered tough and pliable.

The cost of the process is said to be about one-fourth of that of galvanizing, while the durability under similar conditions promises to be greatly extended. H. HAUPT.

ON THE LABORATORY APPLICATION OF RAOULT'S METHOD FOR THE DETERMINATION OF MOLECULAR WEIGHTS.—K. Auwers (*Berliner Berichte*, **21**, 701). Raoult has shown that the lowering of the freezing point of a liquid occasioned by the solution of any substance is a function of the molecular weight of that substance, and has deduced formulæ by which molecular weights may be calculated from observed lowering of the freezing points. The method has been experimentally verified with several solvents by Blagden (*Phil. Trans.*, **58**, 277), Coppet (*Pogg. Ann.*, **114**, 63; **116**, 55; **145**, 599), and again by Raoult (*Ann. Chim. Phys.*, **4**, **23**, 366; **25**, 502; **26**, 98; **5**, **20**, 217; **28**, 133; **6**, **2**, 66, 93, 99, 115; **4**, 401; **8**, 289, 317).

If *C* be the lowering of the freezing point occasioned by the solution of *P*

grammes of substance in L grammes of the selected liquid, and A the depression occasioned by one gramme of the substance in 100 grammes of the liquid,

$$A = \frac{C \cdot L}{P \cdot 100}$$

The value A is named by Raoult the coefficient of depression for the substance and liquid, and its product when multiplied by the molecular weight M of the dissolved substance, yields a value $M \cdot A = T$, which he calls the "molecular depression" of the substance. The value of A varies with the nature of the substance, and like that of T, with the nature of the solvent, but when the same solvent is employed, T remains sensibly constant for large classes of substances of analogous chemical constitution. In other words, substances of similar chemical constitution exert the same molecular depression.

The law has been still further investigated by Raoult, who shows that if the calculation be made for the depression T_1, caused by the solution of one molecule of the substance in 100 molecules M_1 of the solvent, the value

$$T_1 = \frac{M}{M_1} A = \frac{T}{M_1}$$

is not only constant so long as T remains constant, but that it remains sensibly the same no matter what solvents be employed. Thus, if t_1, t_2, t_3 be the molecular depressions of liquids whose molecular weights are m_1, m_2, m_3,

$$\frac{t_1}{m_1} = \frac{t_2}{m_2} = \frac{t_3}{m_3} = T_1 = \text{constant.}$$

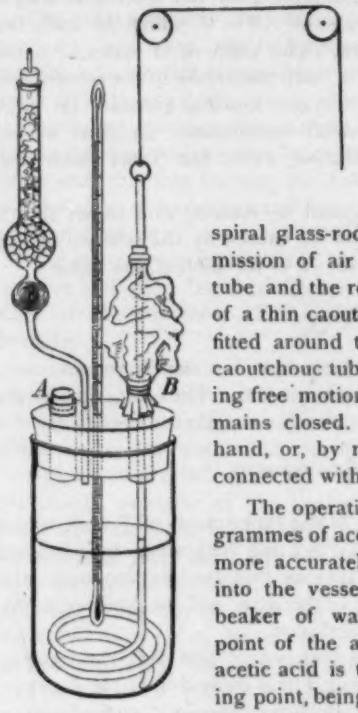
The value of this constant, according to the experiments of Raoult, varies between 0°·59 and 0°·65, and the mean is 0°·63, and the law may be expressed as follows: If one molecule of any substance be dissolved in 100 molecules of any chosen solvent, the freezing point of the latter will be lowered 0°·63. Raoult names this the general law of congelation.

The law holds good for temperatures between 0° and 80°, the freezing points of the solvents used by Raoult lying within these limits. It does not appear to apply in the case of water, with which the value of T_1 varies between 0°·92 and 1°·27 for carbon compounds, and is different for each class of salts, a fact probably depending on a not fully understood chemical action.

The liquid best adapted for the determinations is crystallizable acetic acid, and even when the substance under experiment is hygroscopic it is not necessary that the acid shall be perfectly dry, for while the result of the first experiment may be erroneous, the substance already introduced will have taken any small quantity of water present, and the introduction of a second and a third quantity will produce constant results. The molecular depression of acetic acid is about 39.

It must be well understood that the method does not yield absolute results; it cannot be used as a substitute for the determination of vapor densities, but it will prove of immense service in cases where the determination of vapor densities is impracticable or impossible.

The apparatus required for the experiments is quite simple. A beaker, 4·5 or 5 cm. in diameter and 13–16 cm. high, is fitted with a caoutchouc stopper pierced with four holes. Through the central hole passes a good thermometer, graduated, say, from 9° to 50° in one-tenth degrees, and the bulb of the thermometer should be in the middle of the liquid. Behind the thermometer a calcium chloride tube is adapted to one of the openings for the drying of the air, which enters as the vessel is cooled. Through the third opening passes a short, wide tube, which is closed by a cork that is only removed to drop in a crystal of acetic acid, in order to start the congelation. The other opening is also fitted with a short tube through which passes, without friction, the stem of a spiral glass-rod agitator, and that there may be no admission of air in the space between the walls of the tube and the rod, the latter is passed through the wall of a thin caoutchouc balloon, the opening of which is fitted around the extremity of the tube; a very thin caoutchouc tube will answer the same purpose, allowing free motion up and down, while the opening remains closed. The agitator may be moved by the hand, or, by means of a cord and pulleys, may be connected with a small water motor.



The operation is conducted as follows: About 100 grammes of acetic acid—the weight need not be known more accurately than to decigrammes—are introduced into the vessel, and the latter is placed in a large beaker of water, cooled 1° or 2° below the melting point of the acetic acid; that is, to about 14°. The acetic acid is then cooled to ½° or ¼° below its freezing point, being constantly stirred by aid of the agitator, and a crystal of acetic acid is then dropped into the liquid. The mercury then falls two- or three-tenths of a degree, but soon begins to rise, at first rapidly, then slowly; in a short time a maximum is attained, after which the temperature slowly falls. The maximum temperature is read to the $\frac{1}{100}$ths of a dègree by the aid of a magnifying glass, and this temperature is accepted by Raoult as the true freezing point. The apparatus is then removed from the beaker of water, and placed on a water bath, care being taken that the steam does not touch it. As soon as the acetic acid is perfectly liquified, a second determination of its freezing point is made in the same manner as the first; the result of the second experiment is 0°·01, 0°·02 or even 0°·03 below that of the first, and a third determination will sometimes show a still further depression of 0°·005. The differences are probably to be explained by the moisture on the walls of

the vessel and in the balloon at the beginning of the experiment, and the substance, whose molecular depression is to be determined, should not be introduced until the freezing point of the acid is constant in two determinations; sometimes two are sufficient—four may be required. As soon as a constant freezing point is indicated, the substance under experiment, accurately weighed to milligrammes, is dropped into the apparatus through the wide tube, and after it has been dissolved by stirring, three determinations of the freezing point are made; the greatest difference between the first and third will be about 0°·01. A second weighed quantity of the substance is then introduced, and three more determinations made, the differences observed in this series being similar to those in the first.

The required time is about ten minutes for each determination; three or four hours will suffice for a series of, say, eleven consecutive determinations with all the manipulations and weighings. W. H. G.

GEOLOGY.

GEOLOGICAL MAP OF EUROPE.—Those readers of the JOURNAL who are interested in geography or geology, are notified that the subscription list to the Geological Map of Europe, which the International Geological Congress is to issue shortly, is nearly complete, but twelve more copies remaining to make the century assigned to the United States. As almost all, if not all, the leading institutions of learning and of research in the country are subscribers to this map, it is time for those who desire to avail themselves of the opportunities of securing it, at twenty per cent. less than its market price, and before it is sold to the general public, to send their names in to Dr. Persifor Frazer, Secretary American Committee, 201 South Fifth Street, Philadelphia. The cost of the map to institutions will be $21, and to individuals $26, the difference being the duty, which to the former class is not chargeable. No money contribution is required until the map is issued, which will probably not be before next fall or winter.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, April 18, 1888.*]

HALL OF THE INSTITUTE, PHILADELPHIA, April 18, 1888.

Mr. JOS. M. WILSON, President in the Chair.

Present, 132 members and fourteen visitors.

Additions to membership since last meeting, sixteen.

The Actuary reported the election, by the Board of Managers, at its meeting held Wednesday, April 11, 1888, of the following persons, to serve as Trustees in accordance with Article I, Section 2, of the By-Laws:

CHAS. HARE HUTCHINSON,	JOHN T. MORRIS,
EDWARD LONGSTRETH,	SAMUEL SARTAIN,
J. VAUGHAN MERRICK,	WM. SELLERS,

JOSEPH M. WILSON.

The Special Committee to prepare a memorial of the late Prof. JAMES CURTIS BOOTH, presented a report which was accepted and referred for publication.

Mr. WM. B. LE VAN read a paper, entitled "The Decline of Engineering: illustrated by Examples drawn from local Practice," which evoked a free discussion. (Referred for publication.)

Mr. W. N. JENNINGS described and exhibited a number of specimens, illustrating a new method of transferring photographs upon porcelain, tiles, celluloid, silk, etc.

F. E. IVES announced that he had succeeded in applying chlorophyl effectively to gelatine-bromide plates, by flowing with the alcoholic solution, then drying, then soaking in water. A paper giving details of experiments has been referred for publication.

The President announced in suitable terms the death of Mr. JOSEPH ZENTMAYER, distinguished for his skill and ability as an optician and maker of microscopes, and who was for many years an active and valued member of the INSTITUTE. The President appointed the following members as a committee to prepare an appropriate memorial of the deceased: Prof. Henry Morton (*Chm.*), Dr. Chas. M. Cresson, Fred. Graff, Geo. H. Perkins and Prof. Coleman Sellers.

Mr. S. LLOYD WIEGAND offered the following preamble and resolutions, and spoke in favor of their adoption by the meeting viz:

"WHEREAS, The promotion of the useful arts and sciences, under the constitution and laws of the United States, granting letters-patent to inventors, has developed inventions so numerous and diversified in character as to embrace devices in almost, if not every, department of the arts, and a record thereof so voluminous that it is difficult and almost impossible for persons not specially trained to ascertain accurately the state of art in any department of manufactures, under which disadvantages many devices are unnecessarily re-invented, and litigation from conflicting claims often ensues; and,

"WHEREAS, The Commissioner of Patents has again recommended the preparation and publication of properly classified abridgements of letters-patent similar to those issued by the British Patent Office, and has clearly shown that the funds accumulated in the United States Treasury, applicable only to purposes of the patent system, are amply adequate to permit such publication, and has recommended Congress to enact such laws as will enable the preparation and publication of such abridgements to proceed; and,

"WHEREAS, The FRANKLIN INSTITUTE, of the State of Pennsylvania, for the Promotion of the Mechanic Arts realizes the importance of rendering easily accessible to persons practically engaged in arts and manufacture, correct information as to what inventions have been patented in the several departments of their work, and the great utility of such classified abridgements of letters-patent in enabling them to attain such information, therefore,

"*Resolved*. That the FRANKLIN INSTITUTE earnestly recommends and urges upon the representatives in Congress to give operative effect to the recommendation of the Commissioner of Patents by enacting promptly such laws as will secure the preparation, by persons of competent skill and knowledge, of concise and thoroughly indexed classified abridgements of patents for invention, and the publication thereof and the placing of such publications on sale at moderate charges, and accessible to the public in libraries for the better diffusion of knowledge on such subjects."

Adopted.

The President was authorized to call a special meeting to be devoted to an exhibition of the operation and capabilities of the improved phonograph devised by Mr. Thos. A. Edison.

Adjourned.

WM. H. WAHL, *Secretary*.

These brief reports of Storms, Fogs, Ice, and Derelicts are intended for
line only for each separate report. Unless otherwise stated, it is understood
direction of wind (not magnetic), and force by Beaufort's scale; temperature

Gale and Storm R

BEGINNING.		LOWEST BAROMETER.					
Date.	Wind.	Date.	Time.	Barometer.		Lat.	
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Fog Reports.

ENTERED.							
Date.	Time.	Lat.	Long.	Temperature.		Date.	
				Air.	Water.		

Ice Reports.

Date.	Time.	Lat.	Long.	Temperature.		Wind.	
				Air.	Water.	Direction.	

These brief reports of Storms, Fogs, Ice, and Derelicts are intended for immediate use, and all the columns should be carefully filled, *one line only for each separate report.* Unless otherwise stated, it is understood that you give Greenwich date (civil), longitude, and time; true direction of wind (not magnetic), and force by Beaufort's scale; temperature in degrees Fahrenheit.

Gale and Storm Reports.

BEGINNING.		LOWEST BAROMETER.						END.		Highest force of wind.	SHIFTS OF WIND. Give compass points to show shifts of wind about time of lowest barometer.
Date.	Wind.	Date.	Time.	BAROMETER. As read off.	BAROMETER. Att. Ther.	Lat.	Long.	Date.	Wind.		

Fog Reports.

ENTERED.						CLEARED.						CHARACTER OF FOG.
Date.	Time.	Lat.	Long.	TEMPERATURE. Air.	TEMPERATURE. Water.	Date.	Time.	Lat.	Long.	TEMPERATURE. Air.	TEMPERATURE. Water.	

Ice Reports.

Date.	Time.	Lat.	Long.	TEMPERATURE. Air.	TEMPERATURE. Water.	WIND. Direction.	WIND. Force.	REMARKS. Description of berg or field.

Derelicts, Wreckage, Buoys Adrift, &c.

Date.	Time.	Lat.	Long.	WIND. Direction.	WIND. Force.	REMARKS. Detailed description of derelict, wreck, &c.

(Form 105—1888.)

REPORT OF MARINE METEOROLOGY.

Month of ....., 18 .

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Commanding.

Masters of vessels of the mercantile marine, on arrival at any port in the United States or Canada, will please forward this blank, in the franked addressed envelope provided for the purpose, to the nearest Branch Hydrographic Office. In any foreign port hand it to the U. S. Consul, who is authorized to forward it with his official mail.

RECEIVED AND FORWARDED BY

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(Communications on any subject relating to navigation may be written hereon, and will receive immediate attention and acknowledgment.)

To the Hydrographer to the Bureau of Navigation, Navy Department, Washington, U. S. A.

SIR:

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Very respectfully,

Name: .....

Address: .....

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UNITED STATES HYDRO

REPORTS OF MARINE

DROGRAPHIC OFFICE.

NE METEOROLOGY.

WATERSPOUTS OFF THE ATLANTIC COAST OF THE UNI

[SUPPLEMENT TO THE PILOT CHART OF THE NORTH

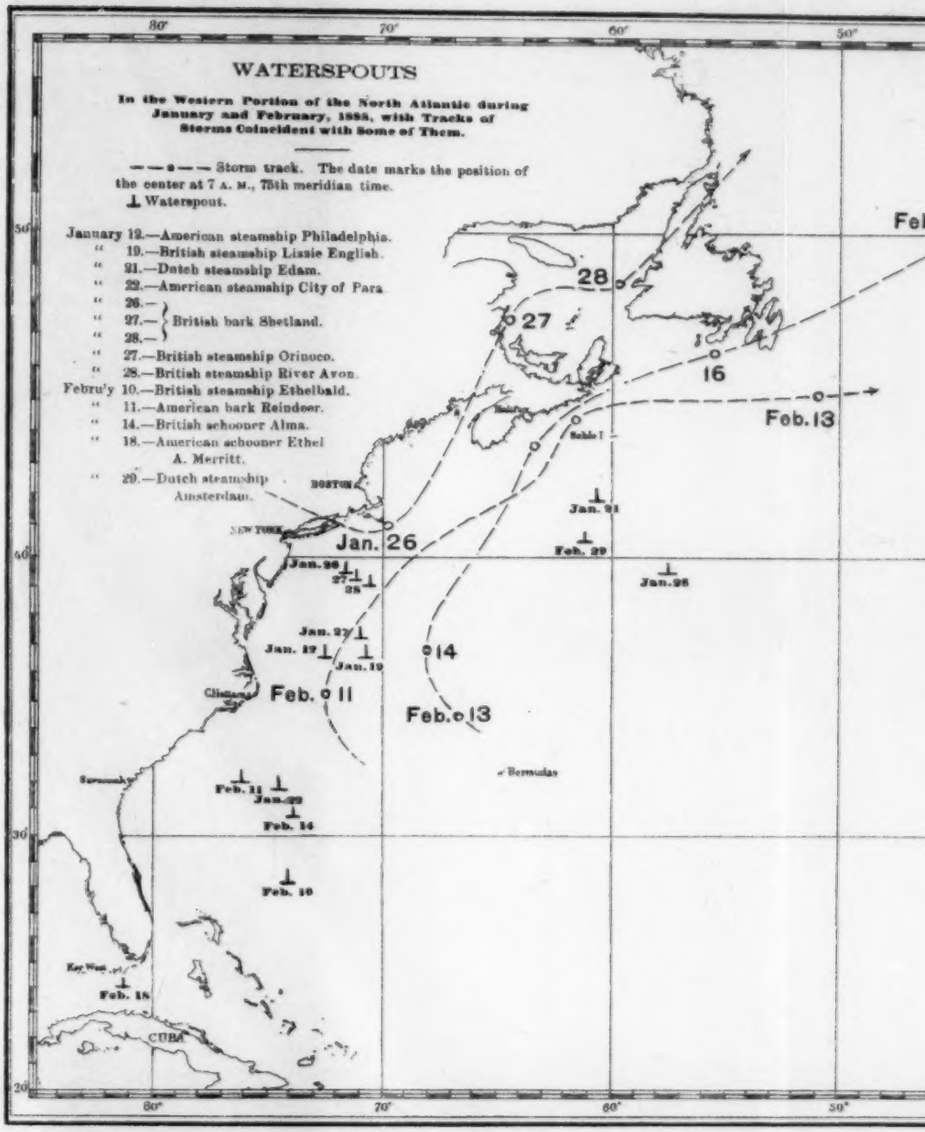
So many interesting reports have been received relative to waterspouts sighted by masters of vessels during January and February in the western portion of the North Atlantic, that advantage is taken of this opportunity to refer to them at greater length than can be done on the Pilot Chart itself, where, however, their positions are plotted graphically by means of an easily recognized symbol. Although the reports now at hand for these two months were received from incoming vessels only, yet they are very characteristic, and indicate fairly well the regions were these phenomena are of most frequent occurrence.

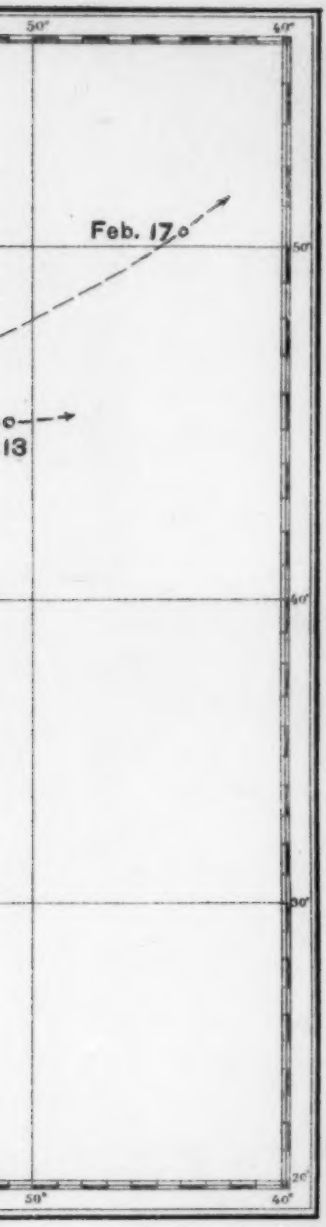
Before quoting the reports themselves, it may be well briefly to refer to what is known regarding the character and formation of waterspouts, which are simply special cases of whirlwinds and tornadoes, as these are special cases of cyclones, but on a much smaller scale. The general principles underlying all these phenomena may be stated as follows: A layer of warm, moist air at the surface of the ocean happens to have above it a layer of cooler, drier air. This condition of things is one of unstable equilibrium, and sooner or later the warm, light air at the surface rises through the cooler and heavier air above. This process sometimes takes place gradually over large areas, but at other times it is more local, and there seems to be formed in the upper layer a break or opening through which the air of the lower layer begins to drain upwards, as through a funnel. Under favorable conditions—that is, when the differences of temperature and moisture and the supply of warm, moist air at the surface are great—this action becomes very intense, and this intensity is still further increased by the fact that as the air rises its moisture is condensed, the latent heat thus liberated adding to the energy of the rising column of air. Now, as this surface air rushes in and escapes upward through the opening thus formed in the upper layer, it takes up a rotary or whirling motion, the velocity of which increases towards the centre or axis of the funnel, and a suction or partial vacuum is created, as indicated by the low reading of the barometer at the centre of a cyclone or whirlwind. In the case of a great cyclone or hurricane, the direction of rotation is determined by the revolution of the earth about its axis, and the well-known law of storms is founded on the fact that this rotation is, in the northern hemisphere, invariably *against* and in the southern *with* the hands of a watch as you look at a watch laid down with the face up. In the case of tornadoes and waterspouts, this direction of rotation is not so uniform, although the same law holds good in most cases.

When a whirlwind is thus formed over the ocean, water is often drawn up the centre of the whirl some distance, owing to the suction created, and at the same time the moisture in the air is condensed as it rises, so that the name "waterspout" is very applicable. Indeed, sometimes a spout will burst over a vessel and flood her decks with water, as a cloudburst does a mountain side. When a spout is forming, its upper portion is often visible first, seeming to grow downwards from the clouds. By observing carefully with a telescope, however, it will be seen that the motion in the column itself is upwards, although the moisture in the air which is rising is condensed lower and lower down, thus rendering the whirl visible lower down continually, and making it appear to be actually descending.

On January 12th, Captain Hess, American steamship *Philadelphia*, saw four waterspouts in latitude 36° 41′ N., longitude 72° 27′ W. On the 19th, Captain Lawson, British steamship *Lizzie English*, reports several a little farther to the eastward (latitude 36° 41′ N., longitude 71° 40′ W.); and from the Dutch steamship *Edam*, Captain van der Zee, a detailed report has been received from third officer de Boerk of a large spout sighted at 7 A. M., January 21st, latitude 41° 50′ N., longitude 60° 25′ W. In the last case, the spout is described as being small and straight at the base, increasing in size towards the top, where it mingled with the clouds. Ascending currents could be plainly seen; there was a strong westerly gale at the time, with occasional hail and snow; temperature of the air 0° Centigrade; water, 11°; direction of rotation of the whirl, with the hands of a watch.

Another very complete report has been received from Captain Dexter, American steamship *City of Para*, who saw several large spouts, January 22d, in latitude 31° 47′ N., longitude 74° 33′ W. The wind was strong from the northeast and the

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sky overcast, with light scud, but the sea was comparatively smooth. Three huge spouts were seen at once, and six in the course of half an hour. The water seemed to be drawn up from the sea, mounting in spiral columns of tremendous thickness, with a loud, roaring sound. Some of the columns were vertical, some inclined at a considerable angle; all of them increased in size at the top and blended with the clouds. A fine rain or mist filled the air, and continued for some time. The wind soon after changed to east.

Perhaps the most interesting cases of all, however, are those which were reported January 26th, 27th and 28th, for the reason that they were clearly associated with a low-barometer area of considerable energy, which moved across the great lakes on the 25th and was central off Nantucket on the 26th. It has been clearly shown by the United States Signal Service that when tornadoes occur on land, they take place almost invariably in the southern quadrants of an area of low barometer. It might therefore be expected that whirlwinds and waterspouts would sometimes be found associated in a similar way with a cyclonic storm at sea. The following reports seem to leave no doubt that such is the case: The area of low barometer, which was central over the great lakes January 25th, barometer 29·7, gathered increased energy when it reached the Atlantic, and off Nantucket the following day the barometer read 29·2, and in the Gulf of Newfoundland, on the 27th and 28th, it read as low as 28·6. The cold, dry northwesterly winds in the western quadrants of this cyclone and the warm, moist air flowing into the eastern quadrants mingled to the southward of the storm centre and gave rise to the conditions most favorable to the development of tornadoes on land and waterspouts at sea. Accordingly, Captain Haskell, British bark *Shetland*, reports that on the 26th, in latitude 39° 34′ N., longitude 71° 16′ W. (a little to the southward of the storm centre), he saw a large spout; the following day (latitude 39° 12′ N., longitude 70° 44′ W.), he saw several more; and on the 28th still more. Captain Garvin, British steamship *Orinoco*, reports that on the 27th, when entering the Gulf Stream from the north, in about latitude 37° 20′ N., longitude 70° 40′ W, the sea was covered with thick vapor from five to fifteen feet high. The heavy, low-lying clouds seemed to draw the vapor up, and many waterspouts were formed, both large and small; temperature of the water, 60° F.; air, 40°. Captain Cleary, British steamship *River Avon*, states that on the 28th, in latitude 39° 30′ N., longitude 57° 20′ W., he saw what he took to be a heavy squall to the southeast. Upon looking at it with his glass, he saw that it was a whirlwind, raising the water to a great height. It must have been over a mile in diameter, but he hesitates to even estimate the height to which the water was raised or the size of the spout, although it must have had terrific power. Shortly afterwards a smaller one passed close to the ship, whirling along the water and raising the spray to a height of fully 100 feet. Even as far south as Bermuda, the conditions were the same, for on the 27th a whirlwind swept across the parishes of Southampton and Warwick, unroofing houses, blowing down trees and damaging property generally.

Similarly, two cyclonic storms, which seem to have originated about the Bermudas on the 10th and 12th of February, as indicated in the weather review published on the March Pilot Chart, were attended by waterspouts, at least one of which was disastrous to shipping. February 10th, at 9 A. M., Captain Smith, British steamship *Ethelbald*, in latitude 28° 28′ N., longitude 74° 06′ W., reports a large spout travelling in a northeasterly direction, rotating, apparently, with the hands of a watch. The barometer was rising; fresh, variable winds, mostly southerly, and sky overcast, with very heavy rain. At this time, the American bark *Reindeer*, Captain Strandt, was about 200 miles to the westward of the *Ethelbald*, running up the coast towards New York, in the Gulf Stream. On the 11th, the weather became squally, with light southerly winds, and at 10 30 A. M., in latitude 32° 04′ N., longitude 76° 06′ W., when the vessel was under full sail, a heavy waterspout passed over her, completely dismasting her below the heads of the three lower masts. No previous warning was received; the weather was apparently clear at the time, and the whole affair was over in a few minutes. The dismasted vessel reached Bermuda on the 16th. Again, when the second of these two cyclonic storms was central about latitude 39° N., longitude 67° W., Captain Hogan, British schooner *Alma*, passed within two miles of a large spout which was travelling from west to east. This was at 2 P. M., February 14th, latitude 30° 40′ N., longitude 73° 50′ W., and it was blowing a gale from N. NW. at the time. The meteorological conditions prevalent about this time between the Bermudas and the Atlantic coast of the United States are well illustrated by a report made by Mr.

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Lund, British steamship *Rothiemay*, Captain Olsen. This vessel arrived at Philadelphia February 20th, from Montevideo. From February 1st (latitude 19° N., longitude 58° W.) to 9th (27° N., 73° W.), fine, pleasant weather, with occasional showers; light to fresh breezes from southeastward. From the 9th to the 14th (34° N., 74° W.), rainy and very unsettled weather; wind mostly from southwestward, but often falling calm and flying to the opposite point of the compass, where it soon died out; thunder and very vivid lightning all around the horizon, but most marked to the NW. and NE. On the 13th (34° N., 75° W.), calm and light variable airs, followed by a breeze from N. NE., which by midnight increased to a whole gale. Similarly, Captain Paine, American barkentine *Henry Warner*, reports that during January 21st, 22d and 23d, off the coast of New Jersey, he encountered light airs going around the compass two or three times every twenty-four hours, exhibiting this same tendency towards the formation of incipient whirlwinds and waterspouts, indicative oftentimes of the gradual generation of a great cyclonic storm.

A still later report, and one of the best and most detailed which has recently been received, relates to a spout sighted by Captain Battle, American schooner *Ethel A. Merritt*. This was on February 18th, latitude 24° 05′ N., longitude 81° 14′ W., in the Gulf Stream, off Key West, about midway between the Florida cays and the coast of Cuba—only a week after the *Reindeer* had been dismasted about 500 miles to the northeastward. There was a light breeze from the northeast at the time, and the sky was about half-covered with nimbus clouds, moving slowly. Just after a light squall had passed by, the first appearance of a waterspout was indicated by the formation of a whirlwind, gradually increasing in size. It was cylindrical in shape below, spreading out above and rotating in a direction with the hands of a watch. When within about 100 yards of the vessel, its angular altitude was about 35°, which would indicate a height of only 230 feet, or less. It was moving to the southwest at the rate of about eight miles an hour. At the base it was transparent, and descending currents seemed to be plainly visible, causing the water at the surface to fly in all directions. Temperature of water, 76°; of air, 83° before, 78° at the time of spout, and 80° afterwards; barometer, 30·10, and fluctuating. A heavy shower of rain accompanied the spout, and the phenomenon lasted in all about ten minutes. A brief report just received from Captain Bakker, Dutch steamship *Amsterdam*, states that a waterspout was sighted February 29th, latitude 40° 34′ N., longitude 61° 05′ W. Weather, squally; wind, NW.; force, 6.

Although the study of such reports has already greatly increased our knowledge of the origin and nature of these interesting and often destructive phenomena, much yet remains to be done before we can hope to be able fully to understand the laws by which they are governed. That portion of the North Atlantic from the northern coast of Cuba to the fortieth parallel, and from the Atlantic coast of the United States to the Bermudas, is pre-eminently a region where waterspouts are liable to occur, owing largely to the warm, moist air which hangs over the Gulf Stream and the cool, dry air brought over it by the northwesterly winds from off the coast. A glance at the Pilot Chart, which shows the general course of the Gulf Stream and the position where waterspouts have been reported, indicates this fact very clearly. This great warm ocean current is now beginning to reassert itself after a period of comparative quiescence during the winter months, and with increasing strength and volume is approaching its northern limits as the sun moves north in declination. Captain McKay, British steamship *Pavonia*, found a current setting his vessel twenty knots a day to the northward in latitude 42° 26′ N., longitude 57° 23′ W., January 22d. Captain Gerry, American barkentine *Levanter*, encountered a strong current setting about NE. by E., below Hatteras, with heavy tide rips, February 20th, latitude 34° 35′ N., longitude 75° 50′ W., and again on the 24th, when twenty-five miles SW. from point of Lookout Shoals. Finally, Captain Freeman, American steamship *Hudson*, at New York, February 28th, from New Orleans, reports a five-knot current in the Gulf Stream, in the Straits of Florida. The warm, moist air overhanging this great "river in the ocean," and the cool, dry air brought down from the coast and from over the cold-inshore current to the northwest, are thus the elements whose intermingling generates these dangerous whirlwinds on the ocean.

The attention of masters of vessels is again called to the desirability of making full and accurate reports of these, as of other marine phenomena, by means of which our knowledge can be still further increased. The most important observations regarding a waterspout are the temperature of the air and water, the reading of the barometer, direction and force of the wind, and the changes which take place in each while the spout lasts. Also, the direction of rotation of the whirl, and an estimate of its size, character and changes of form, with, if possible, sketches, however rough, of its appearance at the various stages of its formation and progress. Many naval vessels are now provided with photographic apparatus, and portable cameras are in such common use by travellers that it may not be too much to expect that advantage will be taken of some favorable opportunity to secure instantaneous photographs from the deck of a vessel to illustrate these remarkable phenomena. Such photographs would be of the greatest value and interest to this Office.

EVERETT HAYDEN,
Division of Marine Meteorology.

J. R. BARTLETT, *Commander, U. S. N.*,
Hydrographer to the Bureau of Navigation.